Radiological Health Data and Reports

VOLUME 8, NUMBER 12
DECEMBER 1967
(Pages 675-740)

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service

SYMBOLS, UNITS, AND EQUIVALENTS

Symbol	Unit	Equivalent
BeV	billion electron volts	GeV
Ci	curie	3.7×10^{10} dps
cm	centimeter(s)	0.394 inch
cpm	counts per minute	
dpm	disintegrations per minute	
dps	disintegrations per second	
eV	electron volt	1.6×10^{-12} ergs
g	gram(s)	
GeV	giga electron volts	1.6×10^{-3} ergs
kg	kilogram(s)	1,000 g=2.205 lb
km^2	square kilometer(s)	
kVp	kilovolt peak	
m^3	cubic meter(s)	
mA	milliampere(s)	
mCi/mi^2	millicuries per square mile	0.386 nCi/m^2 (mCi/km^2)
MeV	million (mega) electron volts	1.6×10^{-6} ergs
mg	milligram(s)	
mi^2	square mile(s)	
ml	milliliter(s)	
mm	millimeter(s)	
nCi/m^2	nanocuries per square meter	2.59 mCi/ml^2
pCi	picocurie(s)	10^{-12} curie=2.22 dpm
R	roentgen	
rad	unit of absorbed radiation dose	100 ergs/g

INTERNATIONAL NUMERICAL MULTIPLE AND SUBMULTIPLE PREFIXES

Multiples and submultiples	Prefixes	Symbols	Pronunciations
10^{12}	tera	T	tĕr' a
10^{9}	giga	G	jĭ' ga
10^{6}	mega	M	mĕg' a
10^{3}	kilo	k	kĭl' o
10^{2}	hecto	h	hĕk' to
10	deka	da	dĕk' a
10^{-1}	deci	d	dĕs' i
10^{-2}	centi	c	sĕn' ti
10^{-3}	milli	m	mĭl' i
10^{-6}	micro	μ	mi' kro
10^{-9}	nano	n	năn' o
10^{-12}	pico	p	pē' co
10^{-15}	femto	f	fĕm' to

RADIOLOGICAL HEALTH DATA AND REPORTS

Volume 8, Number 12, December 1967

In August 1959, the President directed the Secretary of Health, Education, and Welfare, to intensify Departmental activities in the field of radiological health. The Department was assigned responsibility within the Executive Branch for the collation, analysis, and interpretation of data on environmental radiation levels such as natural background, radiography, medical and industrial uses of isotopes and X rays, and fallout. The Department delegated this responsibility to the National Center for Radiological Health, Public Health Service.

Radiological Health Data and Reports, a monthly publication of the Public Health Service, includes data and reports provided to the National Center for Radiological Health by Federal agencies, State health departments, universities, and foreign governmental agencies. Pertinent original data and interpretive manuscripts are invited from investigators.

The Federal agencies listed below appoint their representatives to a Board of Editorial Advisors. Members of the Board advise on general publications policy; secure appropriate data and manuscripts from their agencies; and review those contents which relate to the special functions of their agencies.

Department of Defense
Department of Agriculture
Department of Commerce
Department of Health, Education, and Welfare
Atomic Energy Commission

CONTENTS

REPORTS

Page

X-Ray Patterns and Intensities from High Voltage Shunt Regulator Tubes for Color Television Receivers 675
H. F. Stewart, N. F. Modine, E. G. Murphy and *J. W. Rolofson*

Measurements of X-Ray Exposure from a Home Color Television Receiver 687
H. J. L. Rechen, T. R. Lee, R. H. Schneider and *O. G. Brisco*

TECHNICAL NOTES

Disposal of Radioactive Wastes from U.S. Naval Nuclear-Powered Ships and their Support Facilities, 1966 699
M. E. Miles and *J. J. Mangeno*

DATA

SECTION I. MILK AND FOOD 703

National and International Milk Surveillance 704

1. Pasteurized Milk Network, August 1967, *PHS* 704
2. Canadian Milk Network, August 1967 708
3. Pan American Milk Sampling Program, August 1967, *PAHO* and *PHS* 708

State Milk Surveillance Activities 709

1. California Milk Network, April–June 1967 711
2. Oregon Milk Network, April–June 1967 712
3. Washington Milk Network, April–June 1967 714

Food and Diet Surveillance Activities 716

CONTENTS—continued

	Page
SECTION II. WATER	717
Gross Radioactivity in Surface Waters of the United States, June 1967, *FWPCA*	718
SECTION III. AIR AND DEPOSITION	721
Radioactivity in Airborne Particulates and Precipitation	721
1. Radiation Surveillance Network, August 1967, *PHS*	722
2. Canadian Air and Precipitation Monitoring Program, August 1967	725
3. Mexican Air Monitoring Program, August 1967	726
4. Pan American Air Sampling Program, August 1967, *PAHO* and *PHS*	727
SECTION IV. OTHER DATA	729
Environmental Levels of Radioactivity at Atomic Energy Commission Installations	729
1. Brookhaven National Laboratory, January–June 1967	729
2. Los Alamos Scientific Laboratory, Calendar Year 1966	731
Reported Nuclear Detonations, November 1967	732
Annual Subject Index, Volume 8	733
Annual Author Index	738
Acknowledgments	739
Synopses	iii
Guide for authors	Inside back cover

RADIOLOGICAL HEALTH DATA AND REPORTS

Published under the direction of

James G. Terrill, Jr., Director and
Dr. Raymond T. Moore, Deputy Director
National Center for Radiological Health

by the Standards and Intelligence Branch
Donald L. Snow, Chief

BOARD OF EDITORIAL ADVISORS

Dr. Harold O. Wyckoff
Department of Defense
Dr. Ronald G. Menzel
Department of Agriculture
Dr. Wilfrid B. Mann
Department of Commerce
Robert E. Simpson
Food & Drug Administration, DHEW
John A. Harris
Atomic Energy Commission

STAFF

Managing Editor
Samuel Wieder
Assistant Managing Editor
Charles F. Coyle
Senior Technical Editor
Marvin Rosenstein
Technical Editors
Warren A. Brill
Kurt L. Feldmann

Address correspondence to the Managing Editor, *Radiological Health Data and Reports*, National Center for Radiological Health, Public Health Service, Rockville, Md. 20852.

For subscriptions to *Radiological Health Data and Reports*, please use the order form on last page of this issue.

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service • National Center for Radiological Health

Reports

X-ray Patterns and Intensities From High Voltage Shunt Regulator Tubes for Color Television Receivers

H. F. Stewart, N. F. Modine, E. G. Murphy and *J. W. Rolofson*[1]

Recently, X-ray emission from some color television receivers greater than the NCRP recommended maximum came to the attention of the Public Health Service. The radiation came from a high voltage shunt regulator tube. This discovery prompted a general investigation by the Public Health Service of radiation emission from regulator tubes used in color television receivers. This report describes the construction of high voltage shunt regulator tubes, laboratory test methods, and the measured X-ray distributions in direction, quality, and intensity from 327 shunt regulator tubes.

The X rays generated within television tubes and other high voltage, high vacuum devices, have long been recognized as potential causes of radiation exposure (*1–5*). In 1960, the National Committee on Radiation Protection and Measurements (NCRP) published the following recommendation with regard to the maximum permissible dose from television receivers:

> ". . . from a genetic point of view even sources of minute radiation are of significance if they affect a large number of people. X rays emitted by home television sets are, therefore, of interest because of the high percentage of the population involved. In order to insure that the television contribution to the population gonad dose will be only a small fraction of that due to natural background radiation, the NCRP recommends that the exposure dose rate at any readily accessible point 5 cm from the surface of any home television receiver shall not exceed 0.5 mR per hour under normal operating conditions" (*6*).

The distance of 5 cm was specified to make practical the use of ionization chambers as detection devices. In the same year, the International Commission on Radiation Protection made a recommendation identical to that above (*7*). British Standards Institution Publication 415 of 1957 states, in part, ". . . the X radiation from any equipment containing electronic devices, such as high voltage cathode-ray tubes and rectifying valves, shall nowhere exceed 0.5 mR/hr when measured on the outside surface of the equipment housing" (*8*). The NCRP also changed its recommendation for the dose to the skin of the whole body in this low energy photon range to read, "The maximum permissible dose to the skin of the whole body shall not exceed 30 rems per year and the dose in any thirteen consecutive weeks shall not exceed 10 rems." (*6*).

Description of high voltage shunt regulator tubes

In black and white television receivers the regulation of the high voltage for the picture tube is not necessary for satisfactory operation. Color picture tubes, on the other hand, require precise voltage regulation to insure proper focusing of their three electron beams on the three small bits of red, green, and blue phosphor within each image element on the

[1] Dr. Stewart is director, X-Ray Exposure Control Laboratory (XECL); Mr. Modine is acting chief, Dosimetry and Calibration Unit, XECL; Mr. Murphy is chief, Technical Services Unit, XECL; and Mr. Rolofson is assistant chief, Dosimetry and Calibration Unit, XECL, National Center for Radiological Health.

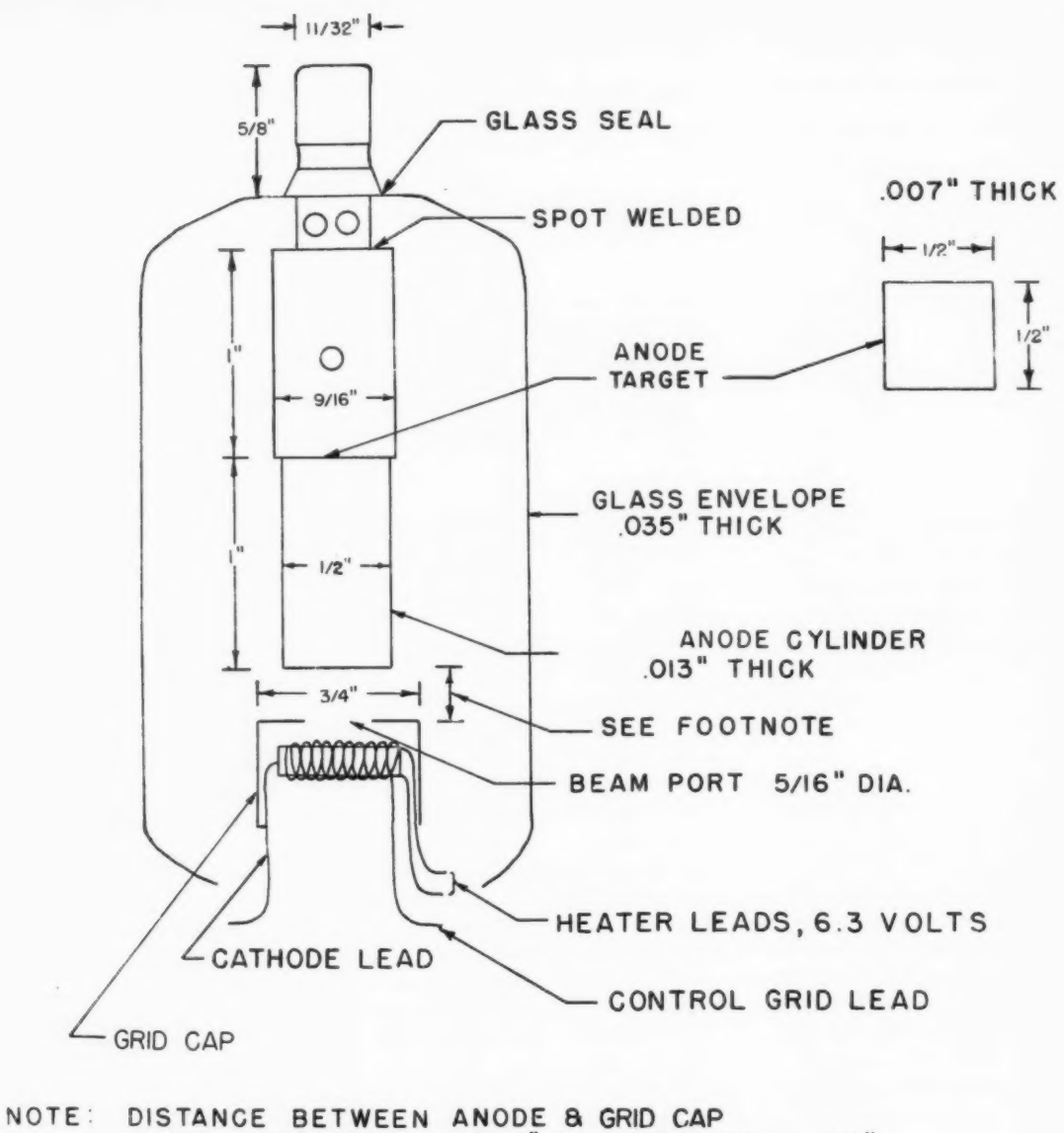

Figure 1. Construction of RCA labeled 6EF4 and GE labeled 6LC6 shunt regulator tubes

screen. Many color receivers achieve this regulation by means of a high voltage shunt regulator tube in the high voltage supply, while other receivers utilize circuit designs which regulate the high voltage without the use of a shunt regulator tube. Table 1 identifies and describes some of the shunt voltage regulator tube types commonly used in color television receivers. These tubes are all quite similar electronically but differ in the number of base pins, internal connections, and internal mechanical configuration. Figure 1 is a sketch of the 6EF4 and 6LC6 types. Shunt regulator tubes in table 1 are low-current, high voltage, beam triodes. A regulator tube maintains a constant accelerating voltage on the picture tube under varying currents which then produce the image brightness and color changes. The control circuit for the shunt regulator tube makes it take that portion of the constant total current from the power supply which is not being used by the picture tube. When the picture is bright, little current goes through the shunt regulator tube; a dim scene shunts more of the current through the shunt regulator tube, which must always sustain the full accelerating potential. Therefore, X rays of varying intensity, but constant accelerating potential, are produced at the target, a molybdenum plate in the anode of the shunt regulator tube and are emitted in all directions when a color television set is operating. The X rays emitted laterally are attenuated by the anode cylinder, generally composed of iron, and by the glass envelope.

The grid cap shown in figure 1 is just large enough to intercept all the X rays directed downward. However, a small lateral misalignment of the grid cap with the anode cylinder or a small angular tilt of the latter could allow X rays from the target area of the anode to pass downward alongside the grid cap and out through the glass envelope. Such an escape of X rays was detected in many of the tests reported here. X rays were projected downward through the base of the tube in the form of a crescent-shaped cross sectional area. The angle from vertical of this downward projection ranged from 18 to 29 degrees.

Recently, shunt regulator tubes have been developed and are being used to replace those found to emit excessive radiation levels. These new tubes are designed to limit the amount of X-ray leakage to a maximum of 0.5 mR/hour, such as that stated in the GE Product Information sheet for the 6LH6 tube: "X-radiation is measured at a distance of four inches from the tube with a potential of 25 kilovolts applied to the anode and a current of 0.5 milliamperes flowing to the anode. These measurements should be made with an ion chamber rate meter which has been properly calibrated or corrected for accurate response in this energy range and which has a window diameter of at least 3½ inches."

The reduction in radiation leakage was achieved by making the following four structural changes:

1. The diameter of the grid cap was increased so that alignment of the anode cylinder with the cap was less critical.
2. The bottom edge of the anode cylinder was rolled inward to form a lip.

Table 1. Shunt regulator tubes for color television receivers

Tube type	Brand name	Actual mfr.	Date of initial production	Design maximum plate voltage	Design maximum plate current	Notes
6BD4	RCA	RCA	12/53	20 kV	1.5 mA	
6BD4A	RCA	RCA	3/54	27 kV	1.5 mA	Supercedes 6BD4.
6BK4	SYL	See note	Before '63	27 kV	1.6 mA	Tube designed by RCA, but manufactured by Sylvania.
6BK4	RCA	RCA	10/54	27 kV	1.6 mA	
6BK4A	RCA	GE	4/63	27 kV	1.6 mA	
6BK4B	RCA	RCA	2/65	27 kV	1.6 mA	Rolled lip on bottom of anode cylinder similar to 6BK4A; interchangeable with 6BK4 & 6BK4A.
6EA4	GE	GE	9/64	27 kV	1.6 mA	Replaced by 6EH4.
6EH4	GE	GE	4/67	27 kV	1.6 mA	Replaces 6EA4 rolled lip on bottom of anode cylinder.
6EF4	GE	GE	5/66	27 kV	1.6 mA	Replaced by 6EJ4.
6EJ4	GE	GE	4/67	27 kV	1.6 mA	Replaces 6EF4.
6LC6	GE	GE	1/67	27 kV	1.6 mA	Replaced by 6LH6.
6LH6	GE	GE	4/67	27 kV	1.6 mA	Replaces 6LC6.
6LJ6	GE	GE	4/67	27 kV	1.6 mA	

3. A short sleeve was inserted next to the target area of the anode inside the anode cylinder to absorb more of the X rays emitted laterally from the target.
4. The glass thickness was increased from 0.035 inch to 0.05 inch.

Test methods and equipment

In order to observe the X rays in all directions from different shunt regulator tubes, simple test stands were built on which a shunt regulator tube was mounted outside of the television receiver. A typical stand had a ⅛ inch hardboard platform on legs high enough for radiation surveys underneath. Atop this stand were placed first an X-ray film packet and then a 4½ inch high pedestal, which held a regulator tube socket wired to the corresponding socket in a General Electric television receiver. High voltage was measured from anode to ground with a portable multimeter (Simpson Model 260) and probe before each series of tests and tube current was read during each test on a milliammeter. The Simpson meter was compared with a 0–50 kilovolt electrostatic voltmeter brought to the laboratory by GE representatives and was determined to be two percent high at 25 kilovolts. This probe drew only 25 microamperes at 25 kilovolts and therefore did not significantly lower the high voltage from a television receiver power supply giving more than 850 microamperes.

One special shunt regulator tube test set was built to provide a means of testing some of the tubes under more precise control of voltage and current. It was composed of a wooden table with a set of tube sockets on pedestals wired to special power supplies for low and high voltage. Figure 2 is a simplified schematic of the circuit. A high voltage constant potential power supply (Sorenson Model 9030–5) provided the anode voltage with a maximum ripple of 1.5 percent at 5 milliampere. The output voltage of this power supply was controlled by varying its input voltage with a Variac. The Variac, in turn, was powered from a General Radio type 1570 line voltage regulator to insure minimum changes in anode voltage throughout a given test. The current through the anode of the tube was controlled both by filament current and by grid bias. A Variac was used to set the current of the filament transformer, thus, controlling the temperature of the cathode. A variable regulated d.c. power supply was included in the cathode circuit to provide grid bias. The high voltage was ordinarily mon-

SHUNT REGULATOR TUBE TEST CIRCUIT

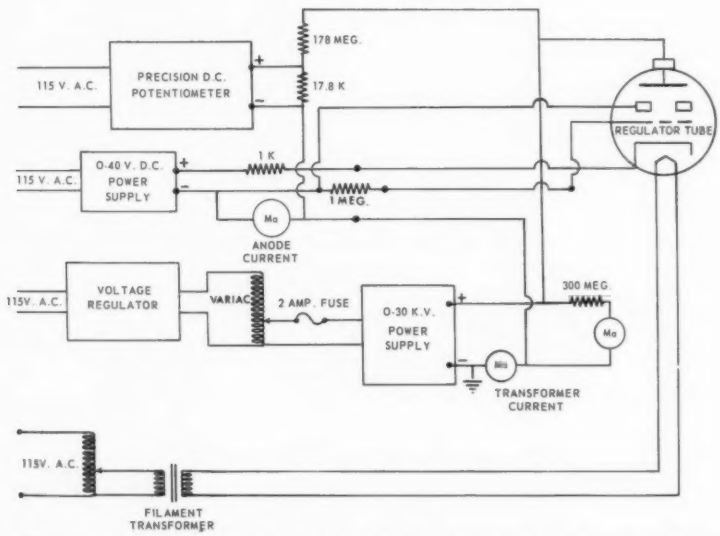

Figure 2. Diagram of the special test circuit used for evaluating X-ray leakage from some of the shunt regulator tubes

itored with a microammeter in series with a 300 megohm resistor. At 30 kilovolts, 0.1 milliampere was drawn by the 300 megohm resistor. A precision electronic potentiometer connected to a bank of high voltage resistors, whose values had previously been accurately measured, and drawing 0.16 milliampere at 30 kilovolts provided a calibration of this voltmeter.

The radiation patterns and intensities were measured with three types of detectors, ion-chamber rate meters, Geiger-Mueller count-rate meters with window probes and X-ray film in paper packages. Each detector was calibrated against the response of the free air, ion chamber for soft X rays of the quality range (25 to 30 kilovolts and 0.15 to 0.3 mm aluminum half-value layers) produced by the shunt regulator tubes and under television operating conditions. The portable ionization chamber rate meter and the free air ionization chamber were alternately aligned in a broad X-ray beam uniform to better than 0.5 percent over the 3½-inch diameter of the portable window. A similar substitution method was used to calibrate the X-ray film, held behind a rotating lead sector wheel with an acceptance window ¾ inch wide by 4 inches high. The Geiger-Mueller rate meter was intercompared with the portable ionization chamber rate meter in the broad beam from a superficial therapy X-ray machine suitably filtered. The calibration factors for each type of detector varied less than 10 percent from the average over the X-ray quality range of interest.

The calibrations enabled conversion of scale readings to accurate exposure rates in an X-ray beam broad enough to cover the entire aperture of the radiation detectors with a uniform intensity. Geometric corrections for partial irradiation of the ion chamber rate meter and the G-M count-rate meters were obviously not obtainable *a priori* by calibration because the crescent-shaped X-ray beams covered fractions of even the G-M window varying from ⅔ to less than 1/100, as shown by comparison with corresponding film measurements in the free air ion chamber. Film density readings provided the only accurate exposure rate measurements of the narrow downward X-ray beams. The other two types of detector were relied on for routine exposure measurements when initial film tests had determined that the X-ray beams were nearly uniform, *e.g.*, laterally and upward.

Measurements were made at significant points around more than 300 shunt voltage regulator tubes. These included samples of a dozen or more of each of eight types of shunt regulator tubes (6LC6, 6LH6, 6EF4, 6EA4, 6EJ4, 6EH4, 6BK4A, and 6BK4B) purchased from local electronics supply houses in the Washington, D.C. area during May 1967. The open market samples totaled 127 shunt regulator tubes. Two hundred additional tubes (100 6EF4's and 100 6LC6's) were supplied by the General Electric Company.

The radiation measurements were made at the following locations around the regulator tube:

1. The point in a plane 11 inches below the target area of the anode of the tube at which a Geiger probe, with window pointed toward the target area, gave the maximum reading. In case of misaligned electrodes, this point approximately located the downward crescent-shaped beam of X rays coming directly from the anode.
2. The point in a plane 8 inches below the anode target at which the horizontally placed window of an ion chamber rate-meter gave the maximum reading. This process also located and monitored the downward beam.
3. Four points in a horizontal plane through the anode target, equally spaced around a circle with a radius of 12 inches, from which a Geiger probe was aimed toward the anode target. These measurements accurately sampled the lateral X-ray exposure rate.
4. A horizontal area 7 inches below the anode target on which a radiographic film packet was placed. In some cases a distance of 7 inches below the base was used. The film completely recorded and accurately measured the pattern of X rays emitted in the downward direction.
5. A paper-packaged 14- by 17-inch film placed on the inner surface of a cylinder 14 inches long and 5.5 inches in diameter was centered around the tube. This recorded most of the lateral X-ray leakage.

Exposure rates could be estimated at the film's average radial distance of 2¾ inches from the axis.

6. The axial point 12 inches above the anode target at which a Geiger probe window was placed. The upward exposure rate was measured at this point.

Not all these points were measured for all the tubes since techniques were modified during the testing.

Patterns of X-ray emission from high voltage shunt regulator tubes

Figure 3 illustrates autoradiographs of six of the first ten purchased 6EF4 tubes showing varying degrees of misalignment. A Kodak Royal Blue Ready Pack was exposed 9½ inches below each regulator tube anode target operated for 1 hour. The receiver normally gave the regulator tube a high voltage of 25 kilovolts measured from anode to ground and a current

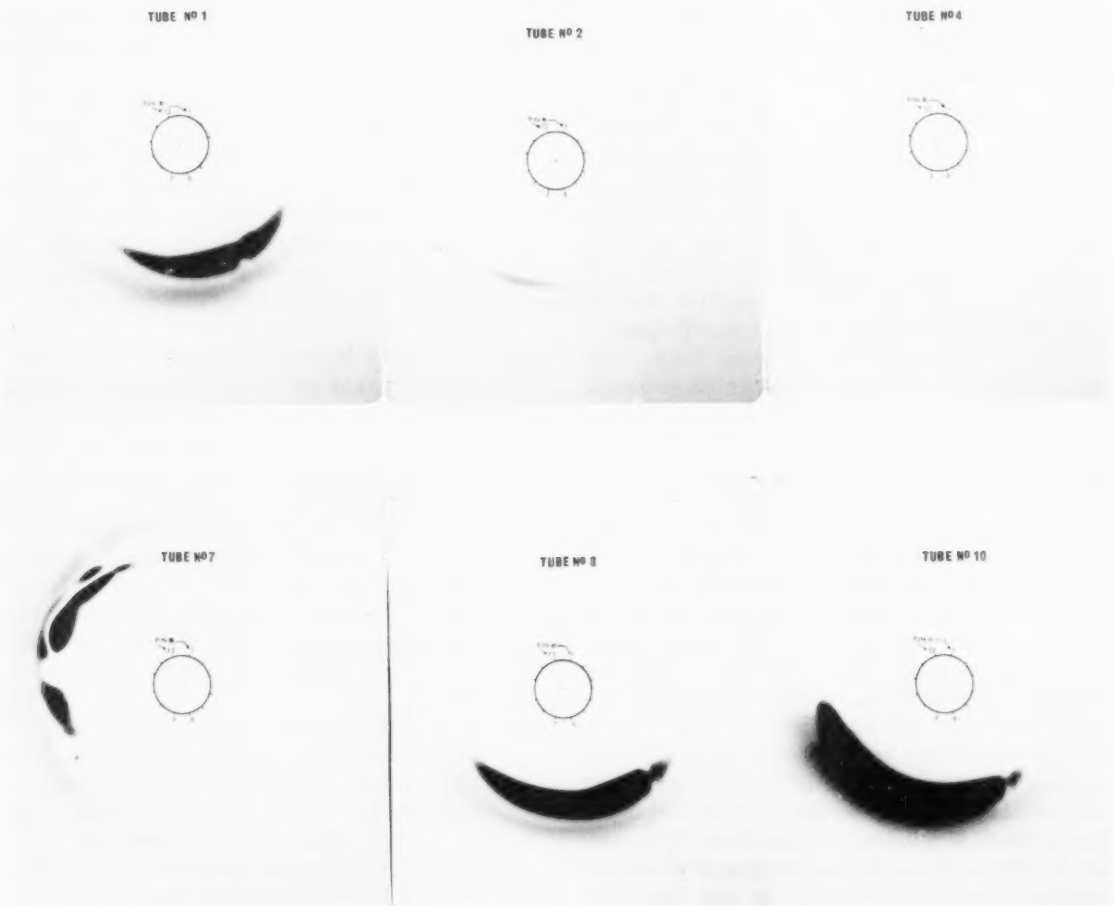

Figure 3. Variation in images of X-ray leakage from misaligned 6EF4 tubes (The 8- by 10-inch film packs were placed in a plane perpendicular to the axis of the tube and 7 inches below the tube base. The circles represent the projection of the tube and pin positions on the radiograph.)

averaging 0.85 milliamperes. Width, angle, and exposure rate measurements of the X-ray leakage patterns from these tubes are included in table 2, which summarizes our data on the first ten 6EF4 tubes purchased for test.

Table 2. Spatial distribution and exposure rate of X-ray leakage detected on photographic film placed below eight shunt regulator tubes of type 6EF4 purchased in the District of Columbia early in May 1967

Tube serial number [a]	Maximum image width [b]	Maximum exposure rate [b] (mR/hr)
1	½	2000
2	⅓	60
3	no image	low
4	½	45
7	¾	1700
8	¾	4000
9	no image	low
10	1	8000

[a] Tubes 5 and 6 were inoperable when tested.
[b] Image was 7 inches below tube base or 9½ inches below X-ray target.

Similar autoradiographs produced by 6LC6 tubes and their 6LH6 replacement tubes, randomly selected from batches of 115 and 10, are shown in the left and right images of figure 4, respectively. The top images resulted from 14- by 17-inch Royal Blue films in Ready Pack looped around the tubes (location 5) and the central images, from like films 7 inches below the tube anode targets (location 4), as suggested by the bottom photograph. The tubes were powered by the special circuit of figure 2 at 27 kilovolts and one milliampere for times sufficient to produce good images. One sees that there is no downward beam of X rays from the new type of tube; the lateral band of X rays is much reduced in quantity and more uniformly distributed. The quantitative differences are discussed later in this report. Similar radiation patterns were observed for the other shunt regulator tubes.

Quality of X rays from shunt regulator tubes

To illustrate the quality of the X rays, an aluminum attenuation curve for the X-ray beam downward from a 6LC6 tube is plotted in figure 5. These measurements were made using a Nuclear Chicago model 2588 survey meter, with a thin-end window model 2526 medium range ionization chamber. This ionization chamber was correct within 10 percent for a broad beam of X rays in the energy region being investigated. Figure 5 shows the half-value layer of the beam to be 0.38 mm of aluminum, which corresponds to an effective energy of 16 keV (*9*). Hayashi *et al.* obtained similar values from 6BK4 tubes (*10*).

Downward X-ray intensities from shunt regulator tubes

Figures 6 and 7 display the readings of a calibrated G–M probe underneath 96 6EF4 tubes and 90 6LC6 tubes, respectively, as cumulated percent frequency curves on logarithmic probability grids. The number of regulator tubes with maximum nominal readings greater than the indicated ordinate, in milliroentgens per hour (mR/hr), as determined by a G-M survey instrument calibrated in an equivalent X-ray field in the same manner used in the X-ray survey, are plotted as percents of the total number of tubes tested. These readings were generally lower than the exposure rates measured by film and were used only to intercompare tubes producing the lower exposure rates.

Figure 8 presents the higher exposure rates recorded on calibrated films placed in a horizontal plane 7 inches under the anode targets of 62 of the 6EF4 tubes. The film was calibrated for X rays of the same quality as those emitted downward from the regulator tubes. When a film was excessively dark, another film was exposed for a shorter time and thus an accurate rate for this severely misaligned tube was calculated.

The eight 6EF4 tubes showing the greatest X-ray leakage represented 12 percent of these tubes and emitted downward beams measuring more than 5,000 mR/hr at the film position. Two 6EF4 tubes, or about 2 percent of the tubes tested gave more than 50,000 mR/hr, one tube showing a leakage of 170,000 mR/hr. G-M probe results are shown in figure 9 for some 6EA4 and 6EF4 tubes that were purchased locally. The small 6EF4 sample included about the same percentages of tubes with G-M

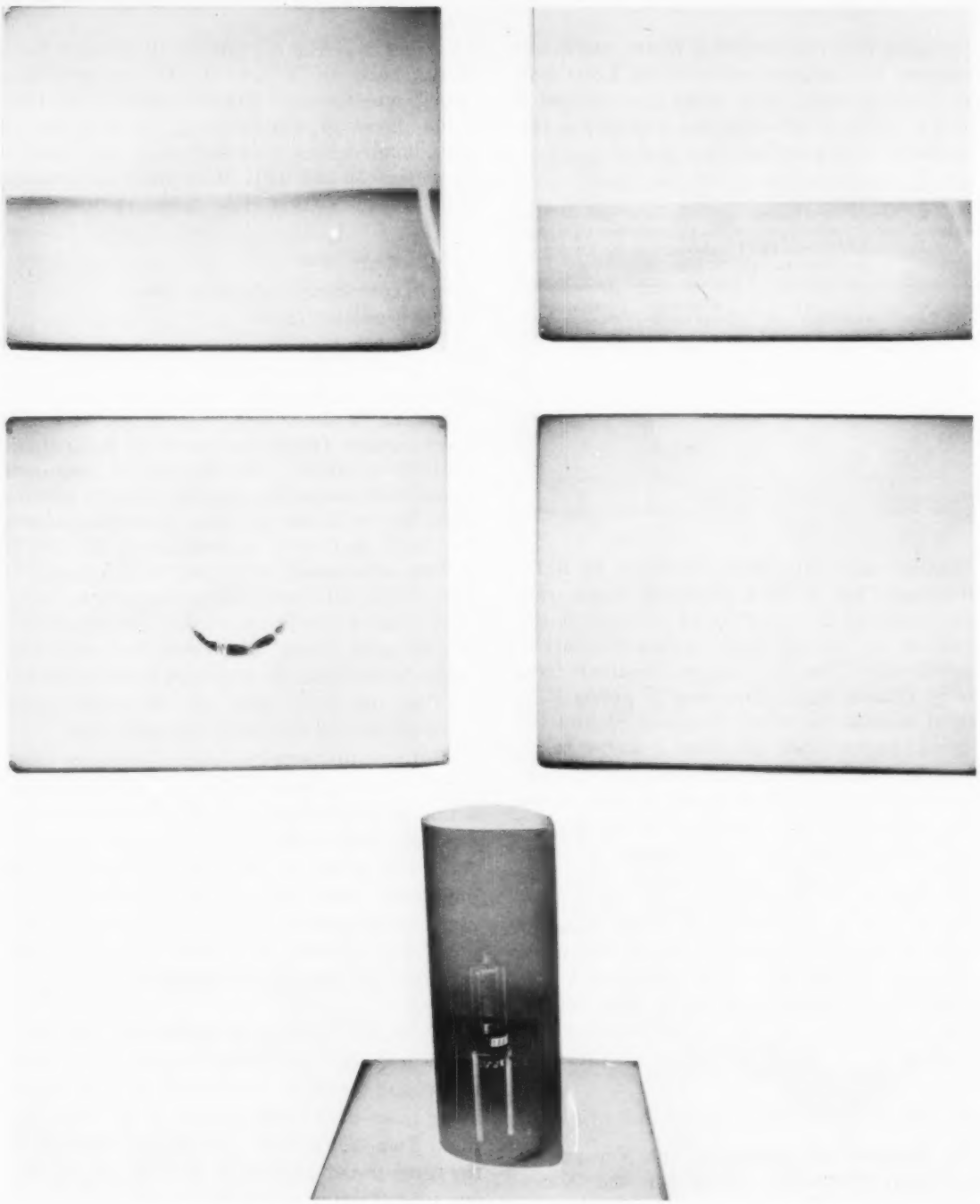

Figure 4. Photograph of radiographic films exposed using shunt regulator tubes (The two films at the left were exposed using 6LC6 tube #212 operated for 95 minutes while the two films on the right resulted from a 39-hour exposure to 6LH6 tube #5. The spatial relationships of tube, wrapped film and flat film are shown in the composite photograph at bottom of figure.)

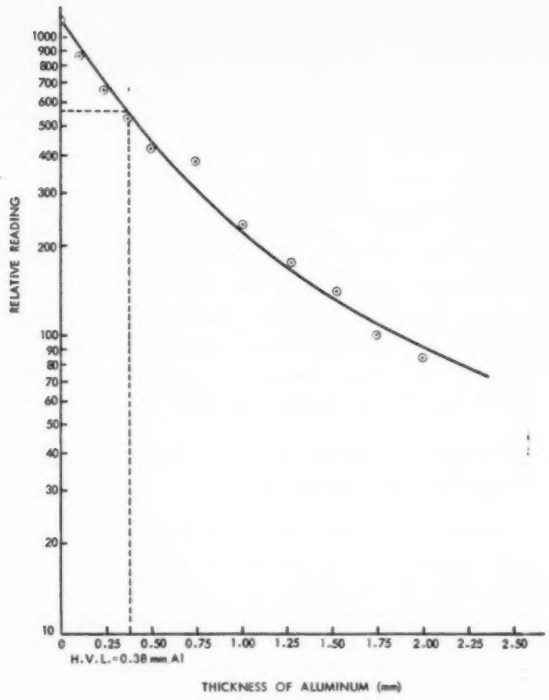

Figure 5. Aluminum attenuation curve of X-rays emitted from a 6LC6 shunt regulator tube operating at 25 kV

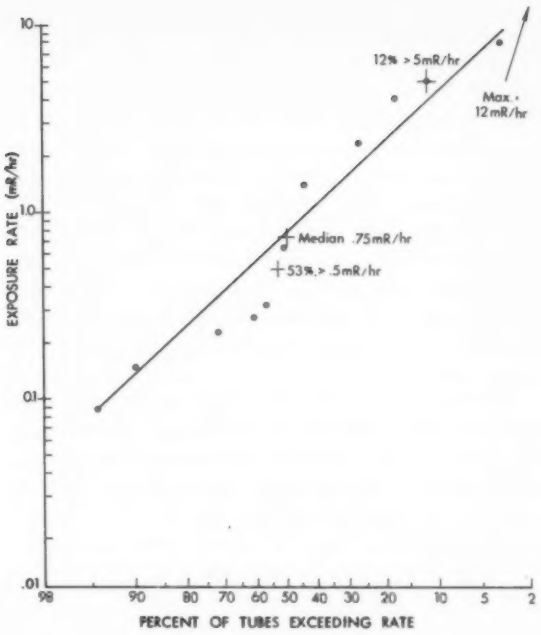

Figure 7. Distribution of maximum E500–B Geiger-Mueller exposure rates 11 inches under anode targets of 90 6LC6 tubes supplied by GE

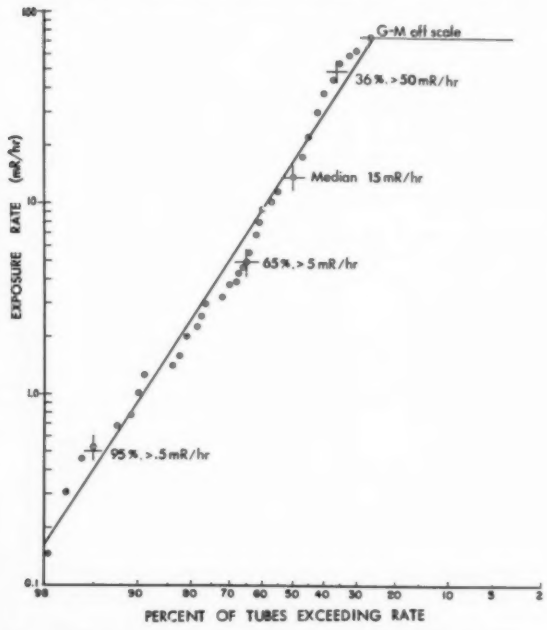

Figure 6. Distribution of maximum RM–3A Geiger-Mueller exposure rate 11 inches under anode targets of 96 6EF4 tubes supplied by GE

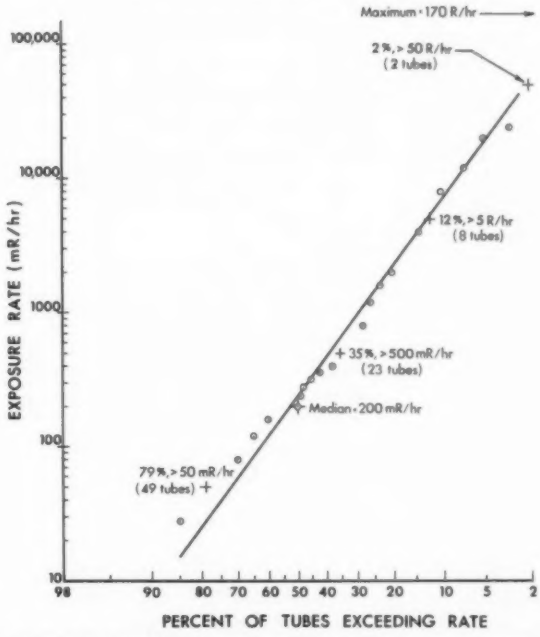

Figure 8. Distribution of maximum film exposure readings 7 inches under anode targets of 62 6EF4 tubes supplied by GE

probe readings greater than 5 "mR/hr" and 50 "mR/hr" as were counted among the large sample of 6EF4 tubes sent by the General Electric Company. The G-M data of figure 9 also shows that the purchased 6EA4 tubes gave more downward radiation than the purchased 6EF4 tubes. Four of the film measurements (25 percent) taken later on these 16 6EA4 tubes gave exposure rates above 5,000 mR/hr, values off-scale for the G-M meter. This type of tube has not yet been studied extensively, but seems potentially the most hazardous of all types measured.

All the other types of tubes measured gave diffuse X-ray patterns of quite low intensities relative to the narrow downward crescents which came from the misaligned 6EA4, 6EF4, and 6LC6 tubes described above. The maximum intensities from the other tubes occurred in the anode target plane, perpendicular to the tube axis.

Intensities in other directions from shunt regulator tubes

The readings taken with an end window G-M probe at four points of the horizontal anode target planes of all the tubes tested are shown in figures 10 to 13 as cumulated percent frequency curves. With the exception of the 6EF4 and 6EA4 tubes the lateral intensities were higher than the downward ones, and the upward intensities were all near background. In one type, the 6LC6 tube, sideward intensities were on the average equal to the downward. In three of the new types of tubes tested, the 6EH4, 6LH6 and 6EJ4, the sideward radiation had been reduced to about 10 percent of that from the old counterpart tubes the 6EA4, 6LC6 and 6EF4, respectively.

Directional distribution of downward maxima from 6EF4 and 6LC6 tubes

During the survey an end window G-M probe was moved around under the platform to find the point of maximum reading. The number of the pin nearest to the maximum G-M probe reading was recorded for each of the 98 6EF4 tubes. Figure 14 shows that all twelve pins scored maxima two or more times and the largest score was 19 for pin 4.

Similar results of pin scores from 63 6LC6 tubes in figure 16 show that this eight pin

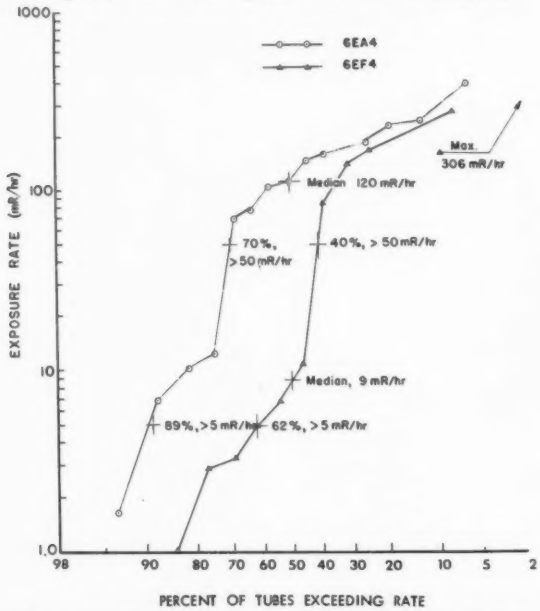

Figure 9. Distribution of maximum E500–8 Geiger-Mueller exposure rates 11 inches under anode targets of 16 6EA4 and 13 6EF4 tubes purchased locally

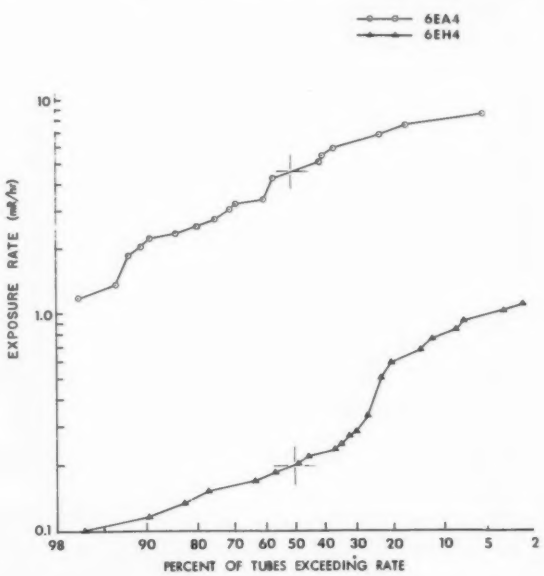

Figure 10. Distribution of E500–B Geiger-Mueller exposure rates 12 inches laterally from anode targets of 16 6EA4 tubes and 22 6EH4 replacement tubes

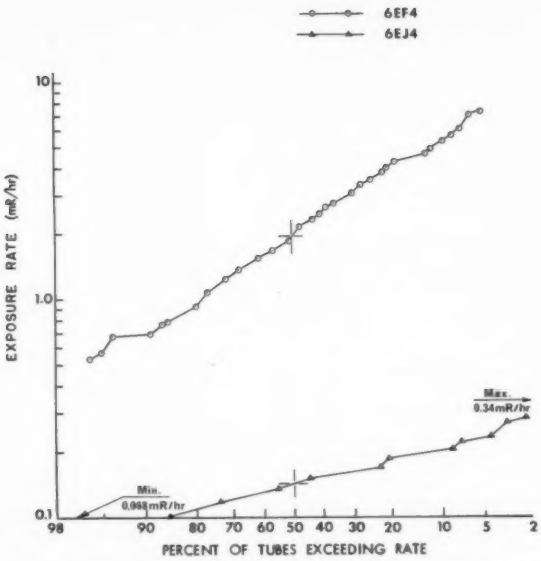

Figure 11. Distribution of E500–B Geiger-Mueller exposure rates 12 inches laterally from anode targets of 100 6EF4 tubes and 23 6EJ4 replacement tubes

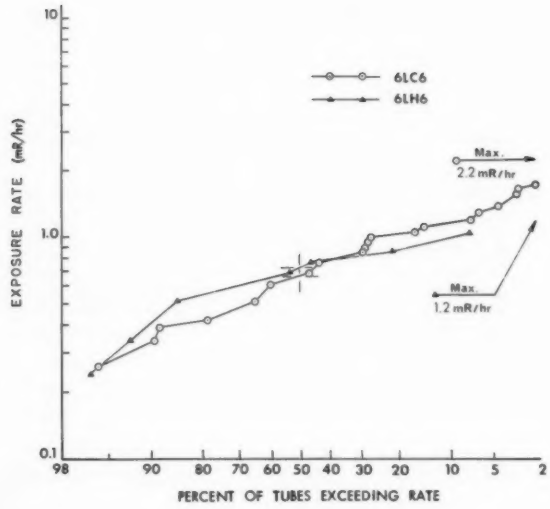

Figure 12. Distribution of E500–B Geiger-Mueller exposure rates 12 inches laterally from anode targets of 100 6LC6 tubes and 22 6LH6 replacement tubes

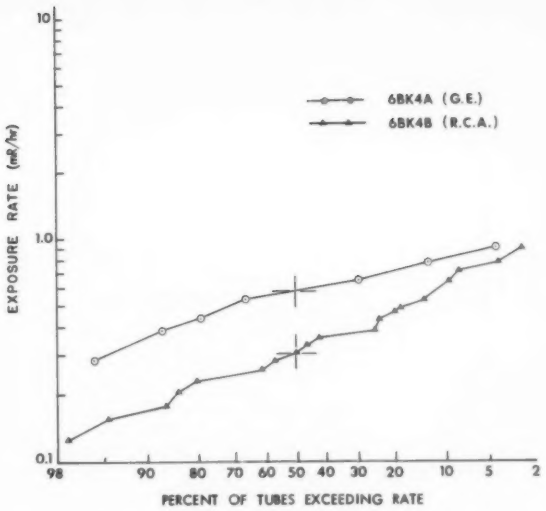

Figure 13. Distribution of E500–B Geiger-Mueller exposure rates 12 inches laterally from anode targets of 6 6BK4A tubes and 13 6BK4B replacement tubes

tube has an equal likelihood of giving a downward maximum in any pin direction except in the direction of pin 1, which appeared about twice as likely to mark the maximum. This random distribution of maximum directions is expected from the mechanical conditions of manufacture, a glassblowing operation.

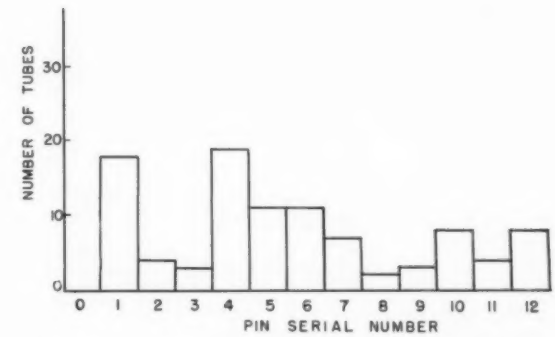

Figure 14. Directional distribution of maximum Geiger-Mueller readings beneath the base of 98 6EF4 tubes

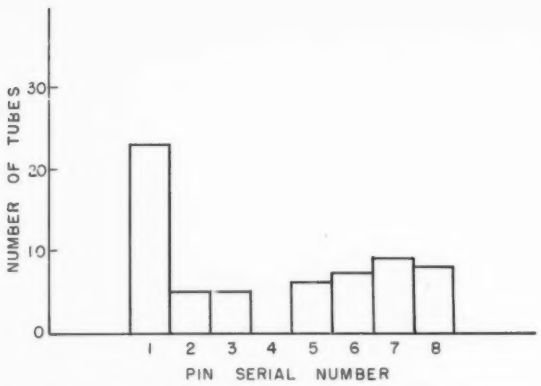

Figure 15. Directional distribution of maximum Geiger-Mueller readings beneath the base of 63 6LC6 tubes

Conclusions

Measured X-ray exposure was highest from those high voltage shunt regulator tubes whose anode structures were not properly aligned with the focusing grid cap, and which had the thinnest glass-tube walls. The amount of X-ray leakage was greatest from those tubes in which the misalignment was apparent visually. Thus, X-ray leakage is likely from any misaligned tube. Use of misaligned tubes as replacements in existing television receivers or as components of newly-produced receivers should be prevented. The more recently manufactured and modified shunt regulator tubes are preferred in all cases in lieu of the misaligned models. Also, external radiation shielding around the shunt regulator tube should be considered for inclusion in future receivers to limit the emitted radiation to the lowest practical level.

Representative products and manufacturers are named for identification only, and listing does not imply endorsement by the Public Health Service and the U.S. Department of Health, Education, and Welfare.

REFERENCES

(*1*) BUSH, A .F., H. T. CASTBERG, and D.G. MacPHERSON. X-ray exposure in manufacture and operation of certain electronic tubes. Public Health Rep 59:1045 (August 1944).

(*2*) LARKS, S. D. Stray X-rays from electron beam instruments and some biological implications. Amer Ind Hygiene Ass Quart 12:175–179 (December 1951).

(*3*) BRAESTRUP, C. B., and R. T. MOONEY. X-ray emission from television sets. Science 130:1071-1074 (October 1959).

(*4*) CALLENDER, M. W., and D. F. WHITE. Aspect of the emission of X-rays from television receivers. J British IRE 21:387–400 (1961).

(*5*) BOURNE, L. B. X-ray hazards from television apparatus and cathode ray tubes. Lancet 6491:510 (1956).

(*6*) NATIONAL COMMITTEE ON RADIATION PROTECTION AND MEASUREMENTS. National Committee on Radiation Protection and Measurements (NCRP). Radiology 75:122 (1960).

(*7*) INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION. Report of Committee II on Protection against X-rays up to Energies of 3 MeV and Beta- and Gamma-rays from Sealed Sources, ICRP Publication 3. Pergamon Press, London (1960) p. 14.

(*8*) BRITISH STANDARDS INSTITUTION. Safety requirements for radio or other electronic apparatus for acoustical or visual reproduction. BSI 415 (1957).

(*9*) DAVISSON, C. M. Alpha-Beta and Gamma-Ray Spectroscopy 1:Chapter II. Interaction of X-Radiation with Matter, Appendix I. Gamma-Ray Attenuation Coefficients (1965).

(*10*) HAYASHI, M., and S. HAYASHI. Absolute dose rate measurement of very soft and weak X-rays by means of a GM counter. J Radiat Res 4:172–182 (1964).

Measurements of X-ray Exposure From a Home Color Television Receiver

H. J. L. Rechen, T. R. Lee, R. H. Schneider and *O. G. Briscoe*[1]

A detailed examination of X-ray leakage has been made for two prototypes of the KC chassis manufactured by General Electric Company for home color television receivers. Typical operating conditions relevant to X-ray production from the high voltage shunt regulator tube and the cathode-ray tube are presented. A selected 6EF4 tube, under operating conditions chosen to produce maximum X-ray emission, produces an exposure rate of 83 R/hour immediately at the floor level under a console receiver, and a calculated maximum exposure rate of 800 R/hour below the receiver.

The results of using two different methods to measure X-ray exposure rates are given, an ion chamber and X-ray film, and the results compare within reasonable limits. Preliminary findings of X-ray emission from the high voltage rectifier tubes are discussed. Little is known of the mechanisms that cause rectifiers to emit X rays, or how such emissions may be controlled other than by shielding.

Recent testimony at Congressional hearings (*1*) has publicized the circumstances by which the General Electric Company distributed about 110,000 home color television receivers potentially capable of emitting X rays greatly in excess of the rates recommended by the National Council on Radiation Protection and Measurements (NCRP) (*2*). The testimony also described the efforts made by that Company, with the assistance of the U.S. Public Health Service, State, and local health agencies, to locate and repair the receivers. The field repair was made by replacing the original high voltage shunt regulator tubes (types 6EA4, 6EF4 and 6LC6) with improved types (6EH4, 6EJ4 or 6LH6), and by readjusting the regulated high voltage supply to the cathode ray tube.

In order that personnel of the National Center for Radiological Health, PHS, might better investigate the problem, GE loaded prototypes of receivers with the KC chassis. Two chassis used the type 6LC6 tube (an octal-based tube) and two used the type 6EF4 tube ("Compactron"[2]). The 6EF4 tube was found to be potentially the most hazardous. Tube type 6EA4 is much like the 6EF4 tube, but was used in few of the KC chassis.

This is a report of the operating characteristics of two color television receivers, chassis type KC, equipped with high voltage shunt regulator tubes type 6EF4. Typical operating conditions that affect X-ray leakage from television receivers using high voltage shunt regulators were studied. Using a randomly selected 6EF4 shunt regulator tube, the relationships observed with two different measuring instruments between operating parameters and X-ray exposure rates beneath, at the face plate, and at the sides of a console receiver are described. Under conditions chosen to produce maximum X-ray emission the magnitude of X-ray exposure beneath a receiver from a selected defective 6EF4 shunt regulator tube (No. 72) is presented. Preliminary measurements of X-ray production from the high voltage rectifier tube are discussed.

X-ray exposure rate from the viewing faceplates of the cathode ray tubes under all typical operating conditions produced X-ray exposure rates well below NCRP recommendations.

[1] Mr. Rechen is deputy chief, Electronic Products Radiation Laboratory (EPRL); Mr. Lee is an electronics engineer; Mr. Schneider is chief, Experimental Physics Unit, EPRL; and Mr. Briscoe is an electronics supervisor; National Center for Radiological Health.

[2] Registered Trademark of GE

The M258CWD is a portable model with a metal cabinet and a molded plastic back. This type is easily mounted on a table, shelf, or brackets, high enough from the floor so that a person might remain underneath it for extended periods close to the bottom of the cabinet. The metal bottom which is not easily removed, shields out all X-rays directed downward from a defective shunt regulator tube, except where the rays may emerge through a series of narrow ventilation slots, or louvers. The emergence and the intensity of the downwardly-directed X rays depend on the exact orientation of the X-ray emission from the defective 6EF4 tube installed in the set. The anode of the shunt regulator (where X rays originate) is 9 cm above the bottom surface of the receiver.

The M970CWD is a console (floor) model, with wood sides about 3 mm thick, and with a hardboard bottom about 6.5 mm thick. There is no metal shielding on the underside of the chassis. This model of the GE receiver, most probably, would remain on the floor. The underside is 22 cm above floor level and the X-ray producing anode of the shunt regulator tube is 9 cm above that, or 31 cm in all, above the floor. Because of the construction of the legs, only objects less than 10 cm high can be inserted under the cabinet from the front and rear. From both sides, an object less than 15 cm high can be inserted under the cabinet for approximately 15 cm. Beyond that, the height limit is 10 cm. The hardboard bottom of the console cabinet attenuates the X-ray beam only slightly (about 44 percent). The slots of the louvers under the shunt regulator tube permit the emergence of an unattenuated X-ray beam.

In both receivers, the high voltage rectifier was placed upside down in a ventilated aluminum cage having a steel back. If X rays are emitted from the high voltage rectifier, they could emerge only from the sides on top of the high voltage cage. Both receivers had thin hardboard or plastic backs. The console model could also readily transmit X rays emitted laterally from the shunt regulator tube.

Definition of terms

Throughout this report, a series of terms, and symbolic abbreviations are used. The following is a list of special terms. Others are explained in the text.

Abbreviation	Units	Description
I_c	milliamperes, mA	Cathode ray, or "picture" tube electron current
I_s	milliamperes, mA	Anode electron current of high voltage shunt regulator tube
I_t	milliamperes, mA	I_c+I_s, total electron current available for regulation
H.V.	kilovolts	High voltage
V_c	kilovolts	Second anode accelerating voltage of cathode ray tube
V_s	kilovolts	Anode to cathode voltage of high voltage shunt regulator tube
VAC	volts, root mean square, 60 Hertz	Household or laboratory line voltage supply
CRT	----------	Cathode ray tube

Typical operating conditions

To measure typical operating conditions of the KC chassis in the console model, a randomly chosen shunt regulator tube (type 6EF4, designated Dallas No. 9), and the original rectifier tube, type 3CN3, were used. Two milliammeters were mounted on an insulating plastic plate, with one used to measure the cathode ray tube current (I_c) and one used to measure the shunt regulator tube anode electron current (I_s). The rated accuracy of the meters was $\pm$ 2 percent of full scale, resulting in a reading accuracy of about $\pm$ 5 percent. The total current available for regulation (I_t) was the sum of $I_c + I_s$.

High voltage was measured to ground with an electrostatic voltmeter Model KVE, 0–10, 20, 30, 50 kV, manufactured by Hallmark Standards, Inc. Line voltage was measured at the line cord plug with a 0–150 VAC Weston taut band meter Model 904. The cathode voltage of the shunt regulator tube was measured with a Simpson Model 260–3 voltohmmeter.

To make a set of measurements, the rear panel high voltage control was set at an arbitrary point. The front brightness control was adjusted to give various values of anode electron current in the shunt regulator tube, from minimum to maximum, while the cathode ray tube current (I_c), cathode ray tube voltage (V_c), shunt regulator tube voltage (V_s), and the line voltage (VAC) were recorded. A dot-bar-color generator maintained a standard pattern on the cathode ray tube. Line voltage was

progressively increased by autotransformer from 90 VAC to 135 VAC.

A series of quasi-linear relationships were observed for V_s and I_t with line voltage, showing that the type of high voltage regulation circuit used in the KC chassis regulated only for changes in I_c and not for changes in line voltage.

Figure 1 shows a typical patern of V_s, I_t and line voltage for the GE KC chassis. The normal color picture tube current, I_c, for a new picture tube, may range from 0.22 to 0.50 milliamperes. The remainder of I_t is shunted by the regulator to the B+ bus of the circuit, so that the high voltage remains relatively constant.

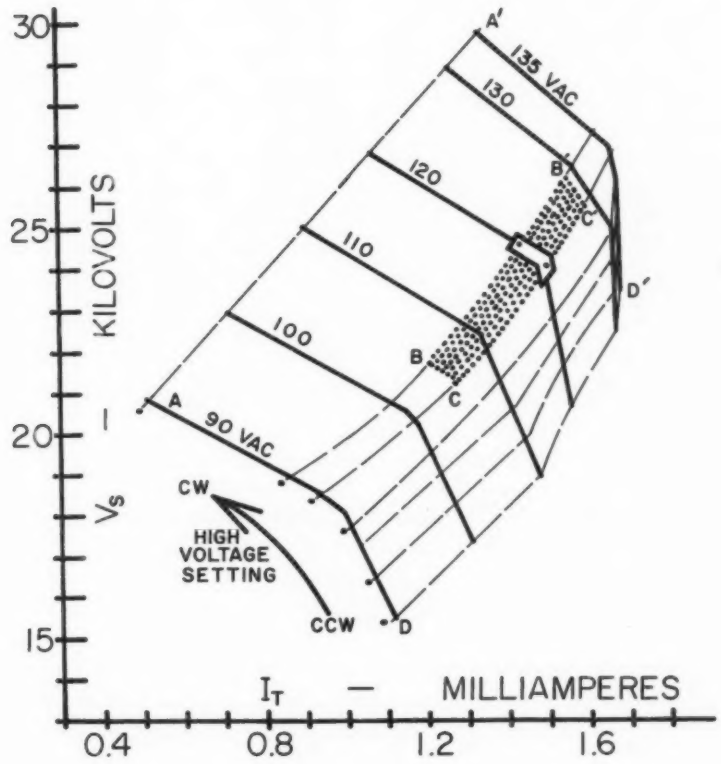

Figure 1. Typical operating conditions of a high voltage shunt regulator tube, type 6EF4 (Dallas #9) in a color television receiver (GE, KC model M970CWD)

AA'—Rear panel H. V. setting for maximum kV
BB'—Rear panel H. V. setting for 24.59 kV at 120 VAC line, the maximum recommended by manufacturer
CC'—Rear panel H. V. setting for 24.09 kV at 120 VAC line, the optimum recommended by manufacturer
DD'—Rear panel H. V. setting for maximum I_t
$I_t = I_{crt} + I_{shunt}$
Dotted zone—Operation region for ± 10 percent change in VAC line.

When the KC chassis is operated with a constant AC line voltage, the high voltage shunt regulator circuit maintains a practically constant kilovoltage on the second anode of the cathode ray "picture" tube for normal operation. A constant total current, I_t, is maintained available for regulation, the sum of the picture tube current, I_c, and the shunt regulator anode current, I_s.

The high voltage from anode to cathode of the shunt regulator tube, V_s, is about 310-460 volts less than the total high voltage rectified to ground, V_c, because the cathode is operated above ground, on the B+ bus. The cathode DC voltage was 3.4 times the line voltage, the regulator control grid voltage has a total excursion of less than 20 volts, negative to the cathode, so one may assume the anode current, I_s, is accelerated by the anode to cathode voltage, V_s. X-ray production from the shunt regulator tube is a function both of V_s and I_s.

The manufacturer recommends that the rear panel high voltage on the KC chassis be adjusted so that V_c is equal to 24.5 kilovolts, and not over 25 kilovolts, with the 60 Hertz AC line voltage fixed at 120 volts R.M.S. Figure 1, a plot of V_s versus I_t, for values of line voltage, shows the manufacturers recommended operating point. With V_c set at 24.5 kilovolts, V_s would be 24.09 kilovolts. The manufacturer's design criteria allow for ± 10 percent variation from design centers for line voltage. Using the data given in figure 1, the shunt regulator parameters observed under conditions within normal design range would appear as in table 1.

In figure 1, the values in table 1 fall along the lines CC′ and BB′. The line CC′ is the range of operation that occurs during ± 10 percent excursions of line voltage with the recommended high voltage setting. The line BB′ represents another operating range within design line voltage variations that would have been obtained if the V_c had been set at 25.0 kilovolts with the line voltage at 120 VAC.

Line AA′, in figure 1, is the clockwise rear panel setting for extreme high voltage, and could be obtained with V_c = 24.5 kilovolts and VAC = 105 volts. This might produce an unsatisfactory picture because of insufficient current through the shunt regulator tube for proper operation.

Table 1. Typical operating conditions of GE console model M970CWD color television receiver

Line voltage VAC (volts RMS)	V_c (kilovolts)	C_s (kilovolts)	I_t (mA)	Assumed normal ranges	
				I_c (mA)	I_s (mA)
Condition CC′ [a]					
128.7	25.60	25.16	1.59	0.22–0.50	1.37–1.09
120.0	24.50	24.09	1.50	0.22–0.50	1.28–1.00
117.0	23.90	23.50	1.46	0.22–0.50	1.24–0.96
105.3	21.58	21.22	1.27	0.22–0.50	1.05–0.77
Condition BB′ [a]					
128.7	26.66	26.22	1.55	0.22–0.50	1.33–1.05
120.0	25.00	24.59	1.43	0.22–0.50	1.21–0.93
117.0	24.40	24.00	1.39	0.22–0.50	1.17–0.89
105.3	22.11	21.75	1.21	0.22–0.50	0.99–0.71

[a] Conditions CC′ and BB′ are shown in figure 1.

The line DD′ in figure 1 represents the extreme counter clockwise setting of the rear panel high voltage control for minimum kilovolts and maximum regulatory current, I_t. This setting normally would not be used because the picture tube voltage would be too low to yield a satisfactory picture.

In the region of CC′–DD′, in figure 1, the power limitations of the high voltage system for each setting have been reached, and the shunt regulator has little control over kilovoltage regulation. This region represents the relationships common to almost all black-and-white television receivers, and those color receivers not having high voltage regulators.

It is of interest to calculate, from figure 1, the care and precision that would be required of a field technician to make a satisfactory high voltage adjustment in accord with manufacturer's recommendations and still insure proper circuit operation. In attempting to make the advised setting of V_c = 24.5 to 25 kilovolts, with 120 VAC, the technician has a range of only 24 to 26.8 kilovolts within which to work before he reaches the upper end of the high voltage adjustment, or loss of regulator control. The accuracy required in measuring kilovoltage is better than one part in 25, or ± 4 percent. Few technicians have high voltage meters rated better than ± 10 percent. If V_c is set erroneously at 26.8 kilovolts, load line AA′ applies for line voltage variations. Within normal operating ranges then, the high voltage could reach 29 kilovolts.

Relationship between operating parameters and measured X-ray exposure rates

Tests were conducted to relate electron current and high voltage to measured X-ray exposure rates at 3 locations:

(a) At the face of the cathode ray "picture" tube, where V_c, the accelerating kilovoltage, and I_c, the electron current, were the factors governing X-ray production,

(b) Below the receiver, at an angle of about 20° from the vertical axis of the shunt regulator tube where a small intense beam of X rays had been detected with a thin-walled GM counter, and

(c) At the left side of the console cabinet. X rays had been detected emerging horizontally from the anode plane of the shunt regulator tube through the left side of the cabinet, and from under the left speaker, in the front, about 30 to 40 cm above floor level. Under all conditions of measurement, exposure rates at the side were twice those at the front.

X-ray production for both (b) and (c) were controlled by V_s, the anode-to-cathode kilovoltage of the shunt regulator tube, and I_s, the tube current.

In all cases, X-ray exposure rates were found to be directly proportional to the electron current being accelerated. All values, therefore, have been normalized to one milliampere and are reported as milliroentgens per milliampere-hour.

Exposure rates were measured with a Victoreen ion chamber model 440 RF. The X-ray energy response of the rate meter over a range of half-value layers of 0.4 to 1.0 mm of aluminum was confirmed by comparison with a Victoreen R-meter having NBS calibration. The instrument was found to be essentially energy independent and to read within 6 percent of true reading when uniformly exposed over the entire chamber at a constant rate.

To measure X-ray exposure rates from the face of the picture tube with the Victoreen 440 RF ion chamber, the tube was operated at several times the normal current and at higher than recommended voltages. The results are given in table 2.

Table 2. X-ray exposure rates from faceplate of picture tube of GE console model M970CWD color television receiver

Accelerating voltage V_c (kilovolts) [a]	Electron current I_c (milliamperes) [b]	X-ray exposure rate (milliroentgens/ milliampere-hour) [c]
30.00	1.00	0.15
28.96	1.00	.10
26.92	1.00	.03

[a] This is the gross V_c. No attempt was made to measure the net accelerating voltage by deducting static charge effects.
[b] Much of the electron current is intercepted by a perforated iron mask in the picture tube.
[c] Victoreen 440 RF ion chamber in contact with faceplate. A full roster with cross-hatch pattern was used.

Because of the low exposure rates at the face of the picture tube attenuation measurements were not made.

To measure the maximum X-ray exposure rates below the receiver, the Victoreen 440 RF was located in the most intense portion of the downward emerging X-ray beam, about 1.2 meters underneath the receiver, which was supported on an elevated frame. A heavy lead mask was fixed about 30 cm below the anode of the shunt regulator tube, the source of the X-rays. The mask had a 7.5 by 7.5 cm aperture which was used to support additional lead collimators and attenuating materials. At 30 cm, practically all of the downward X rays emerged through the 7.5 cm square aperture.

By means of careful masking, the most intense portion of the X-ray beam was localized and was defined by a lead mask with an 0.6 by 0.6 cm aperture placed 15 cm below the anode of the tube, just 5 cm from the lower surface of the console cabinet. The larger lead mask was removed after attenuation measurements were made.

The most intense portion of the X-ray beam, at 117 cm from the tube anode to the center of the ion chamber, was entirely incident on the chamber window, and appeared to fill an area of 22 cm^2, about 4.4 by 5 cm. Because the beam was not uniform, any extrapolation of the measured values would tend to underestimate actual maximum exposure rates. The area of incident X rays, 22 cm^2, was 29 percent of the area of the entrance window of the ion chamber. The readings made at 117 cm, therefore, were multiplied by 3.44 to obtain the estimated exposure rates at that distance. These rates, then, were used as the baseline data for extrapolating in toward the source.

The ion chamber was then moved to 64 cm from the shunt tube anode, and the series of exposure rate and attenuation measurements listed in table 4 were made. To prepare table 4, smooth interpolations were made graphically to provide data for whole number values of accelerating voltage. Corrections were made for air attenuation, which was measured at V_s = 24.06 kV and 28.62 kV, by placing the ion chamber at measured distances along the collimated X-ray beam. Except for air absorption, the reading of the ion chamber did not change with distance from the source, as long as the X-rays were totally incident on the entrance window. Attenuation by air, for practical purposes, appeared to be the same at both voltages, and typical values are given below.

Measured attenuation of 24–29 kV X rays by air

Distance from source, cm	50	75	100	150
Fraction of original exposure rate	0.90	0.86	0.825	0.79

The exposure rate values given in table 3 were calculated from the data obtained at 117 cm and 64 cm for a distance of 30 cm from the shunt tube anode. For known values of V_s and I_s, the readings at 117 cm were multiplied by the factor 3.44 to obtain exposure rate. A correction was applied to allow for the lesser air attenuation at 30 cm, and it was assumed that the corrected exposure rate at 30 cm,

$$R_{30} = R_{117} \times \frac{(117)^2}{(30)}$$

A similar factor was calculated to obtain corrected exposure rates from the measurements made at 64 cm.

In footnotes to table 3 are given the first, second and maximum (heavily filtered) half-value layers in aluminum, and the aluminum equivalent absorber thicknesses of two common building materials.

The maximum exposure rates given in table 3 were confirmed by measurements made with large X-ray films that had been calibrated for X rays in this range of energies, in comparison with cobalt–60 gamma rays. Each 14-inch by 17-inch film, in a paper "ready pack", was exposed 30 cm below the anode of the shunt regulator tube, parallel to the receiver base, masked by lead collimators previously described so that only the most intensely irradiated area was exposed, 4.13 by 4.76 cm. After exposure, the films were given standard development for 5 minutes at 68° F., with nitrogen gas burst agitation. The film was packed with two pieces in each ready pack. Care was taken to have the desired type of film oriented toward the source. After drying, the optical densities were read using a modified Ansco-MacBeth Model 12A densitometer that had a light spot 1.0 mm in diameter. The exposed areas were

Table 3. Maximum X-ray exposure rates at 30 cm below a molybdenum anode 6EF4 high voltage regulator tube operated in GE model M970CWD color television receiver (measured with Victoreen 440 RF ion chamber)

Added [a] attenuation (t) of Al	Maximum X-ray exposure rates [b] at 30 cm, milliroentgens per milliampere-hour										
	Vs—Shunt tube anode—cathode voltage										
	20 kV	21 kV	22 kV	23 kV	24 kV	25 kV	26 kV	27 kV	28 kV	29 kV	30 kV
0.00	52.80	64.70	79.10	99.50	130.00	177.0	243.0	328.0	440.0	577.0	922.0
.25	9.24	20.30	29.70	47.00	72.60	108.0	157.0	219.0	304.0	428.0	569.0
.50	4.21	9.48	18.15	30.50	49.50	77.50	117.0	168.0	242.0	338.0	453.0
.75	2.44	5.45	11.05	19.80	36.00	58.90	93.20	135.0	194.5	275.0	376.0
1.00	1.65	3.54	7.25	14.20	26.70	46.70	74.70	112.0	163.0	231.0	316.0
1.50	0.73	1.82	4.15	8.18	15.90	30.50	50.30	78.40	117.0	171.3	242.0
2.00	.33	0.97	2.41	5.12	10.06	19.80	34.30	55.40	85.10	127.7	186.2
3.00	----------	.26	0.79	1.85	4.14	8.25	15.70	27.40	44.50	70.20	108.7
4.00	----------	----------	.26	0.68	1.78	3.96	7.68	14.70	25.05	40.90	65.10
5.00	----------	----------	----------	.25	0.77	1.88	3.96	7.92	14.34	24.40	39.90
6.00	----------	----------	----------	----------	.33	0.90	2.01	4.37	8.25	14.34	24.35
7.00	----------	----------	----------	----------	----------	.43	1.02	2.44	4.82	8.74	15.00
8.00	----------	----------	----------	----------	----------	.20	0.53	1.32	2.69	5.10	9.06
9.00	----------	----------	----------	----------	----------	----------	.26	0.73	1.53	2.97	5.60
Half-value layers' in mm of aluminum:											
HVL_1	0.06	0.13	0.15	0.24	0.32	0.39	0.44	0.53	0.58	0.68	0.74
HVL_2	.11	.19	.30	.38	.51	.67	.83	.90	1.01	.97	1.23
HVL_{max}	.43	.54	.63	.73	.83	.94	1.03	1.14	1.23	1.33	1.41

[a] The aluminum equivalents of two common building materials were:
Douglas fir interior grade plywood—0.354 mm of Al/cm
Pressed fiber ceiling tile—0.315 mm of Al/cm
[b] Measurements made at 30 cm from anode, 20° from base end of long axis of tube.

scanned by hand, to locate the area of maximum exposure, which was almost uniform over an area measuring about 1.0 by 1.3 cm. Table 4 summarizes the findings.

A comparison of the results of tables 3 and 4 (the appropriate table 3 values are given in footnote [a] of table 4), showed reasonably good agreement between the values calculated from ion chamber measurements and those obtained on the slow "commercial" film, at both 28.62 kV and 24.07 kV. The "commercial" film gave 15 percent lower results at 28.62 kV and 5 percent lower at 24.07 kV, values that seemed to be in excellent agreement with those calculated from ion chamber readings. The fast "KK" film also gave results lower than calculated, 31 percent at 28.62 kV and 25 percent at 24.07 kV, about the lower extreme of substantial confirmation by this method.

Radiation emitted from the left side of the receiver console (about 0.32 cm of hardboard or plywood) was also evaluated with the Victoreen 440 RF ion chamber. With the chamber face 0 6 cm from the cabinet, aimed at the anode-cathode region of the shunt regulator tube, the center of the chamber was 31.4 cm from the anode of the tube. A lead-steel collimator with a 10 cm by 10 cm opening was

Table 4. Maximum X-ray exposure rates at 30 cm below a molybdenum anode 6EF4 high-voltage regulator tube operated in GE model M970CWD color television receiver (measured with X-ray film)

Type of X-ray film (Eastman Kodak Company)	V_s [a] (kV)	HVL_1 (mm of Al)	Energy dependence factor rel. to cobalt-60	Maximum optical density			Exposure time (minutes)	Equiv. cobalt-60 exposure (mR)	Calculated	
				Gross	Base and fog	Net			X-ray exposure (mR)	X-ray exposure rate (mR/mA-hr) [b]
"KK"	28.62	0.75	0.117	0.50	0.24	0.26	1.2	62	7.25	363
"Commercial"	28.62	.75	.117	.44	.08	.36	50	3200	374.4	449
"KK"	24.07	.35	.185	.38	.22	.16	4.0	40	7.40	111
"Commercial"	24.07	.35	.185	.30	.08	.22	150	1900	351.5	141

[a] I_s=1.00
[b] The equivalent rates, from table 3, are 528 and 148 mR/mA-hr at 30 cm, respectively.

Table 5. X-ray exposure rates at 31.4 cm laterally from a molybdenum anode 6EF4 high-voltage regulator tube operated in a GE model M970CWD color television receiver (measured with a Victoreen 440 RF ion chamber)

Added attenuation t (mm of Al)	X-ray exposure rates [a] at 31.4 cm, mR/mA-hour										
	V_a—shunt tube anode—cathode voltage										
	20 kV	21 kV	22 kV	23 kV	24 kV	25kV	26 kV	27 kV	28 kV	29 kV	30 kV
0.00	0.055	0.070	0.091	0.120	0.165	0.230	0.335	0.510	0.800	1.30	2.20
1.00						.026	.062	.147	.292	0.53	0.91
2.00						.0124	.032	.080	.163	.31	.55
3.00							.016	.044	.093	.18	.34

[a] Measurements made laterally opposite anode-cathode, on outside of left side of receiver.

placed in the cabinet half way between the anode and the chamber. Unattenuated readings were made at about 50 values of V_a, and attenuation measurements were made at 28.65 kV and 24.07 kV. The X rays from the side were semihomogeneous in a broad horizontal, slightly downward band, and covered the entire chamber window. The exposure rates appeared to follow the inverse square law with increasing distance out to at least 50 centimeters. Table 5 lists the observed exposure rates, smoothed graphically as was done for table 3, to give values for whole numbers of V_a, the shunt tube anode-to-cathode voltage.

Graphically, comparison of the attenuated side radiation and the attenuated downward radiation for ratios of exposure rates at 28.65 kV and 24.07 kV showed that the side radiation had the attenuation characteristics of downward X rays that had been filtered by an additional 3.0 or 4.0 millimeters of aluminum equivalent, but numerically 6 percent of the equivalent downward value. Below 1.0 mm of added aluminum attenuator, the side radiation had "soft" radiation components that concealed the essentially "hard" nature of these X rays in comparison to the "softer" nature of those emerging downward.

X-ray exposure rates through the front of the cabinet under the left speaker were similar in characteristic to the side radiation, and were one-half the side exposure rates listed in table 5.

X-ray exposure from shunt regulator tube under operating conditions producing maximum X-ray emission

The portable model represents a case where the highest exposure rate might occur because human tissue such as the eye, can be placed within about 10 to 12 cm of the anode of the shunt regulator tube. The area of exposure, however, is small.

The console model represents the case where the maximum area (and volume) of exposed tissue might occur because the underside of the set offers little shielding.

Three conditions of exposure were examined at the Electronic Products Radiation Laboratory. The assumption was made that the same exposure rate was possible below both models of GE color television receivers:

(1) exposure 85.1 cm below the anode of the shunt regulator tube of a floor mounted console receiver, with intervening floor and ceiling equivalent material,

(2) exposure 31 cm below the anode of the shunt regulator tube in the floor mounted console receiver at the upper surface of the floor, and,

(3) exposure 10 cm below the anode of the shunt regulator tube of a floor mounted console receiver, very close to the underside of the cabinet. Except that the area exposed is much larger, this would also simulate the exposure rate at the closest approach to the portable model. Significantly, from this position one can look through the ventilating louvers and see the glowing anode of the shunt regulator tube because the tube is mounted in a cut-out position with no intervening material between the anode and the eye.

The GE color television receiver, model M970CWD console, was operated with a type 6EF4 shunt regulator tube designated experimentally as No. 72, under the following conditions.

Screen brightness—minimum, operation otherwise normal

Signal input—programmed channel

V_c, approximate kV at 6EF4 anode—24.5 kV positive with respect to chassis ground (V_s=24.09 kV)

I_a, anode current—1.4 mA

Line voltage—117 VAC, 60 Hertz

The console receiver was placed on a platform of plywood 0.65 cm thick, which in turn, was elevated 58.3 cm above a concrete floor. The X-ray pattern emerging through the bottom of the set was located and marked.

Measurements were made with paper packages of 14- by 17-inch X-ray film, each containing one fast (Eastman Kodak Company KK) and one slow (Eastman Kodak Company Commercial) non-screen film. The film was processed using standard developing procedures with gas burst agitation. Energy dependence and exposure calibrations were confirmed by the X-ray Exposure Control Laboratory, National Center for Radiological Health. Optical densities were read with a MacBeth-Ansco Densitometer, model 12A, having a light beam 4.0 mm in diameter.

(1) One film pack was exposed, centered on the X-ray pattern, for 30 minutes, 85 cm below the anode of the shunt regulator tube and 54 cm below the surface of the supporting floor. In addition to the shielding provided by the 0.65 cm plywood floor, a layer of 1.91 cm Douglas fir, interior grade plywood and a layer of 1.27 cm compressed fiber acoustic ceiling were added to simulate flooring and ceiling typical of some types of house construction.

(2) One film pack was exposed and centered on the X-ray pattern for 30 minutes, 31 cm below the anode of the shunt regulator tube, on the surface of the supporting floor of 0.65 cm plywood. No intervening shielding except that of the hardwood underside of the TV receiver was present.

(3) From the data obtained in (2), using the inverse square law, the maximum exposure rate 10 cm below the anode of the shunt regulator tube in the floor mounted console receiver was calculated. This is approximately the nearest that human tissue could be placed to the underside of the cabinet.

$$83{,}200 \text{ mR/hr } (31)^2/(10)^2 = 800{,}000 \text{ mR/hr (at 10 cm)}$$

The measured intensities, 640 mR/hr at 85 cm, and 83,200 mR/hr at 31 cm, and the calculated intensity, 800,000 mR/hr at 10 cm, were used to construct the curves on the graph shown in figure 2. The transmission factors of the floor and ceiling material[3] were measured by a Victoreen 440 RF ion chamber corrected for exposure area. The "inverse square" curve was calculated from the point (31 cm, 83.2 R/hr). The free air curve was measured below the television receiver with the Victoreen 440 RF, using a very narrow X-ray beam (4.4 by 5.0 cm). The beam intensity decreases the "inverse" faster than the "square" curve inverse square of distance because of air absorption and scatter. The film measurement of 640

[3] X-ray transmissions of simulated floor of 2.54 cm plywood = 21.4 percent
X-ray transmission of ceiling of 1.27 cm pressed fiber = 68.3 percent
Total transmission of floor-ceiling combination = 14.6 percent

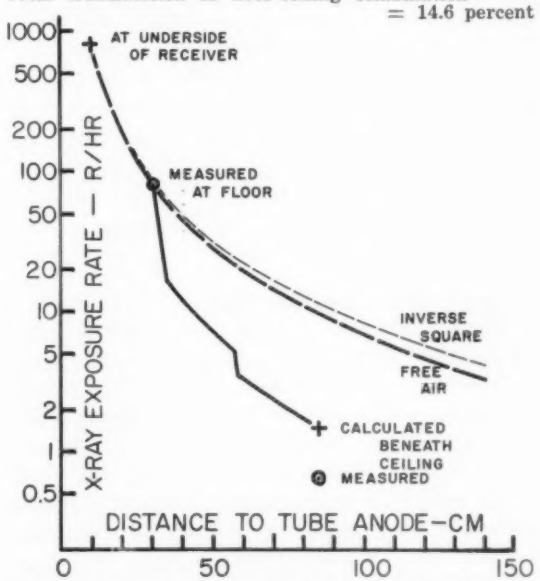

Figure 2. X-ray exposures beneath a GE console color television using type 6EF4, No. 72, regulator tube. Measurements were made with X-ray film at 25 cm below the tube and 85 cm below the tube. All other values were calculated from measured transmission data.

Film data (maximum reading):

Film type	Exposure time (minutes)	Net optical density	Equivalent cobalt-60 exposure (mR)	Assumed half-value layer (mm Al eq.)	Energy correction factor	Corrected exposure (mR/hr)
Commercial	30	0.24	2,000	0.46	0.16	640

Film data (maximum reading):

Film type	Exposure time (minutes)	Net optical density	Equivalent cobalt-60 exposure (mR)	Assumed half-value layer (mm Al eq.)	Energy correction factor	Corrected exposure (mR/hr)
Commercial	30	3.62	160,000	0.20	0.26	83,200

mR/hour at 85 cm was 93.5 percent the expected value, 1,470 mR/hour, that had been calculated from attenuation measurements.

A further test was made to relate scattered radiation to the primary exposure at the floor. Three 14- by 17-inch X-ray films were placed vertically against the cabinet and touching the floor, one on the left side and two on the left front, with the same exposure setup as in (3). Exposure time was 87 minutes. The maximum exposure rates attributable to the X rays from the shunt regulator tube were found near the floor on both the side and left front films.

The maximum rates were 1.6 and 2.2 mR/hr, respectively, or about 1/50,000 to 1/30,000 of the maximum primary exposure rate at the surface of the floor.

X-ray production from the high voltage rectifier tube

During detailed examination of the KC chassis operating in the console model and employing the NaI (TI) scintillation detector, the high voltage rectifier tube, type 3CN3, was found to emit X rays in a wide, horizontal plane (perpendicular to the axis of the tube). The X-ray exposure rate appeared to be low and well within NCRP recommendations under all typical operating conditions, particularly because the tube was partially shielded by a steel flap on the rear of the high voltage cage.

To investigate the condition further, the rear of the case was opened and the time distribution of the X-ray emissions was examined. Typically in the KC chassis, the high voltage pulse which lasts 63.5 microseconds, oscillates 4 or 5 times during the peak inverse cycle across the high voltage rectifier. X rays, in very short bursts, are emitted at the peak of each inverse ripple when the peak inverse voltage may be 30,000 volts. The quantity of X rays was greatest during normal viewing conditions and practically unaffected by changes in front panel brightness or contrast control settings. Instead, the emission seemed to be characteristic of the individual tube and not of the exciting supply, except for the frequency of bursts and the high voltage setting.

The time distribution was found by phase angle analysis of the scintillation detector output with a Victoreen "PIP" 400 channel pulse height analyzer. A linear, 0–10 volt ramp, synchronized to the TV flyback pulse, was used to drive the analog-to-digital converter. A variable-delay pulser and a dual-beam oscilloscope were used to determine the time-location of each X-ray peak relative to the shape of the high voltage flyback waveform.

Later, the high voltage cage of this particular KC chassis was modified to permit the examination of other types of 3-volt high-voltage rectifier tubes. The relative pattern of X-ray production was always the same.

Figure 3 shows the X-ray emission from a type 3BS2 rectifier tube operated in the KC chassis in relation to the flyback pulse waveform. The half-value layer of this radiation in aluminum was found to be 1.00 mm, and constant out to 6 half-value layers for black-and-white TV high voltage rectifiers. The greatest quantity of X rays, in fact, was pro-

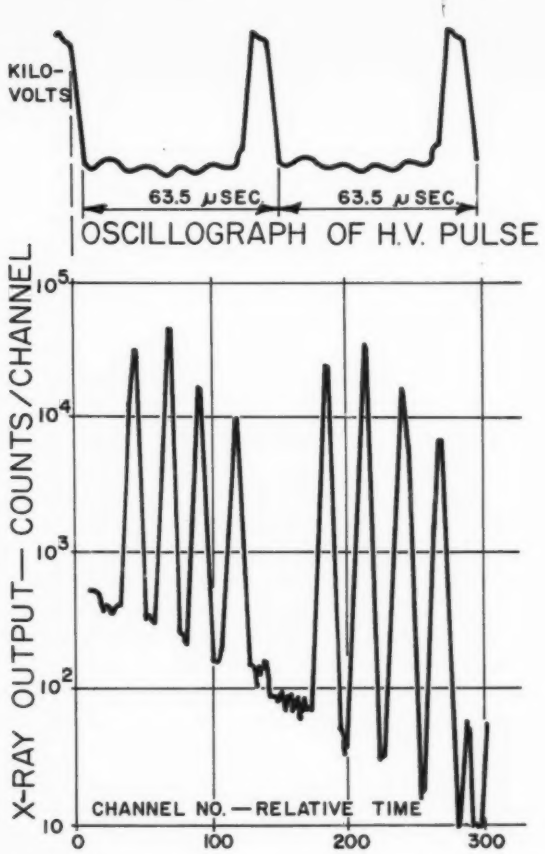

Figure 3. X-ray production during normal operation of high voltage rectifier tube, type 3BS2
TOP—Oscillograph of the high voltage flyback pulse in a color television receiver (GE KC model M970CWD)
BOTTOM—Frequency and relative intensity of short bursts of X rays emitted by rectifier during peaks of inverse voltage.

duced by a series of 1-volt filament tubes operating in a 17 kilovolt black-and-white receiver.

A rectifier with a cold filament emits only a single small burst of X rays during the flyback cycle, when the forward voltage is enough to induce conduction. There is no emission at inverse peaks.

Further testing is planed to devise a way of relating X-ray exposure rates to measurable variables in the high voltage rectifier system in order that quality control methods may be proposed.

REFERENCES:

(*1*) U.S. CONGRESS. Subcommittee on Commerce and Finance, the House Interstate and Foreign Commerce Committee, relative to H.J. Res. 280, Hon. John E. Moss, Chairman, July 31, 1967.
U.S. CONGRESS. Subcommittee on Public Health and Welfare, the House Interstate and Foreign Commerce Committee, relative to H.R. 10790, Hon. John Jarman, Chairman, August 14, 1967.
U.S. CONGRESS. Senate Committee on Commerce, relative to S. 2067, Hon. E. L. Bartlett, August 29, 1967.

(*2*) NATIONAL COMMITTEE ON RADIATION PROTECTION AND MEASUREMENTS. Radiology 173:122 (1960).

(*3*) STEWART, H., N. MODINE, E. MURPHY, and J. ROLOFSON, X-ray patterns and intensities from high voltage shunt regulator tubes for color television receivers. Radiol Health Data Rep 8:675–686 (December 1967).

Representative products and manufacturers are named for identification only, and listing does not imply endorsement by the Public Health Service and the U.S. Department of Health, Education, and Welfare.

Technical Notes

Disposal of Radioactive Wastes From U.S. Naval Nuclear-Powered Ships and Their Support Facilities, 1966

M. E. Miles and *J. J. Mangeno* [1]

This report summarizes data on disposal of radioactive wastes from U.S. Naval nuclear-powered ships and their support facilities and summarizes results of environmental monitoring performed to confirm the adequacy of waste disposal limits and procedures. The waste disposal data presented show that the total long-lived radioactivity in liquid waste discharges associated with operation and maintenance of Naval nuclear-powered ships was 0.39 curies in all harbors in 1966, which is substantially less than the total of 5.38 curies reported discharged in harbors during 1965. Results of environmental surveys of harbor water and bottom sediment for gross radioactivity and for cobalt–60 have shown that, (1) no increase in radioactivity above normal background levels has been detected in harbor water, (2) discharges of liquid wastes from U.S. Naval nuclear-powered ships have not caused a measurable increase in the general background radioactivity of the environment, and (3) low-level cobalt–60 radioactivity is detectable in localized areas of harbor bottom sediment around a few piers at operating bases and shipyards where maintenance and overhaul of Naval nuclear-powered ships have been conducted over a period of several years.

This report confirms that procedures used by the Navy to control discharges of radioactivity from U.S. Naval nuclear-powered ships and their support facilities are effective in protecting the health and safety of the general public.

A detailed description of the means of disposing of radioactive wastes and the sources of these wastes has been presented earlier (*1*). Table 1 lists the total amounts of long-lived radioactivity discharged as liquid wastes into various U.S. harbors during 1965 and 1966. Solid radioactive materials from ships are transferred to a shipyard or other short facility for packaging and disposal. For ultimate disposal, solid radioactive wastes are shipped to AEC-approved burial sites since shipyards and shore facilities are not permitted to dispose of radioactive solid wastes by burial on their own sites. The total radioactivity and volumes of solid radioactive wastes disposed of in 1965 and 1966 are shown in table 1.

Environmental monitoring survey procedures have been described in a previous report (*1*). A summary of the 1966 surveys for cobalt–60 in bottom sediment of U.S. harbors where U.S. Naval nuclear-powered ships have been regularly based, overhauled or built is presented in table 2.

Monitoring for cobalt–60 in harbor bottom sediment is conducted each quarter year by collecting 20 to 100 samples with a 6-inch square sampler. Samples are taken of the top one-half to one inch of sediment in the immediate vicinity of and away from berthing areas used by Naval nuclear-powered ships. These surveys show that the total amount of cobalt–60 observed in bottom sediment near a few piers is small compared to natural radioactivity present in harbors.

Independent checks on sediment have been performed by the U.S. Public Health Service by analyses performed at the Southeastern Radio-

[1] Nuclear Propulsion Divisions, Naval Ship Systems Command, Department of the Navy.

Table 1. Radioactive waste disposal by U.S. Naval nuclear-powered ships and their support facilities [a]

Location	Solid radioactive waste				Liquid radioactive waste [b]			
	1965		1966		1965		1966	
	Hundred cubic feet	Curies	Hundred cubic feet	Curies	Thousand gallons	Curies	Thousand gallons	Curies
1. Portsmouth, N.H. Naval Shipyard	150	2.6	194	9.5	204	0.24	155	0.01
2. Quincy, Mass. Quincy Division	0	0	0	0	0	0	0	0
3. Groton-New London, Conn. Electric Boat Div., State Pier, and Submarine Base	155	353.0	148	1,092.8	828	1.29	1,274	.03
4. Camden, N.J. New York Shipbuilding Corp	0	0	0	0	0	0	0	0
5. Newport News, Va. Newport News Shipbuilding	198	28.0	70	8.9	3,360	1.70	1,581	.06
6. Norfolk, Va. Naval Shipyard and Base	33	1.6	43	2.5	1,146	.44	1,051	.03
7. Charleston, S.C. Naval Shipyard and Base	78	111.5	77	5.6	717	.67	369	.04
8. Pascagoula, Miss. Ingalls Shipbuilding Corp	0	0	0	0	0	0	0	0
9. San Diego, Calif. Navy Pier at Ballast Point	3	0	6	.1	40	.33	0	0
10. Vallejo, Calif. S.F. Bay Naval Shipyard	47	9.4	90	367.0	128	.21	270	.19
11. Bremerton, Wash. Puget Sound Naval Shipyard	4	.1	14	.5	196	.01	0	0
12. Pearl Harbor, Hawaii Naval Shipyard and Base	8	1.4	7	.3	548	.48	654	.03
13. Apra Harbor, Guam	0	0	0	0	69	.01	0	0
Total	676	507.6	641	1,487.2	7,236	5.38	5,354	0.39

[a] U.S. harbors where shipyards and operating bases for nuclear-powered ships are located are included. Other U.S. harbors have had less than 20,000 gallons and less than 0.1 curie discharged per year.

[b] Where discharges in one harbor for a year totaled less than 0.005 curies, "0" is reported in this table. Volumes are reported prior to dilution. Radioactivity data has been standardized to cobalt-60.

Table 2. Summary of 1966 surveys for cobalt-60 in bottom sediment of U.S. harbors where U.S. Naval nuclear-powered ships have been regularly based, overhauled or built

Location	Number of samples with cobalt-60 concentration of: (pCi/cm³)			Total bottom area with cobalt-60 over 10 pCi/cm³ (km²)	Estimated total cobalt-60 in top layer of sediment [a] (Ci)
	<10	10—100	>100		
1. Portsmouth, N.H. Naval Shipyard	174	1	0	0.001	0.007
2. Quincy, Mass. Quincy Division	40	0	0	ND	ND
3. Groton-New London, Conn. Electric Boat Div., State Pier, and Submarine Base	58	215	76	.3	.3
4. Camden, N.J. New York Shipbuilding Corp	61	0	0	ND	ND
5. Newport News, Va. Newport News Shipbuilding	148	0	0	ND	ND
6. Norfolk, Va. Naval Shipyard and Base	341	2	0	.001	.001
7. Charleston, S.C. Naval Shipyard and Base	367	1	0	.001	.001
8. Pascagoula, Miss. Ingalls Shipbuilding Corp	70	0	0	ND	ND
9. San Diego, Calif. Navy Pier at Ballast Point	107	34	0	.01	.001
10. Vallejo, Calif. S.F. Bay Naval Shipyard	436	1	0	.001	.001
11. Bremerton, Wash. Puget Sound Naval Shipyard	140	0	0	ND	ND
12. Pearl Harbor, Hawaii Naval Shipyard and Base	180	100	4	.3	.06
13. Apra Harbor, Guam	75	0	0	ND	ND

[a] All areas with detectable cobalt-60 were in immediate vicinity of piers used for berthing nuclear-powered ships. Minimum detectable radioactivity is approximately 5 pCi/cm³.

ND, not detectable. Where total cobalt-60 is less than 0.001 curie, "ND" is reported.

logical Health Laboratory, Montgomery, Ala., on two samples from each of these harbors each quarter. In addition, a U.S. Atomic Energy Commission laboratory checks some samples from each harbor. Results of these checks have been consistent with results reported in table 2.

Once each quarter, a total of at least five water samples is taken at various locations in each harbor in areas where nuclear-powered ships berth and from upstream and downstream locations. These samples are analyzed for gross radioactivity and for cobalt–60. No harbor water sample has shown detectable cobalt–60 radioactivity. No increases in gross radioactivity of harbor water have been detected.

Twice per year shoreline areas uncovered at low tide are surveyed for radiation levels with sensitive radiation detectors to determine if any radioactivity from bottom sediment washed ashore. All results were in the range of 0.01 to 0.05 millirem per hour, the same as background radiation levels in similar areas.

Throughout the year film badges are posted at locations outside the boundaries of areas where radioactive work is performed. These films showed that radiation exposure to the general public outside these facilities was not above that received from natural background radiation levels.

In addition to the locations listed in table 2, environmental monitoring has been accomplished by U.S. Navy submarine tenders which serve as operating bases for U.S. Naval nuclear-powered submarines in Rota, Spain, and Holy Loch, Scotland. Results of the surveys in the harbor at Rota, Spain, have not shown detectable cobalt–60 in harbor bottom sediment samples. In 1965 in Holy Loch, more cobalt–60 radioactivity than expected was detected in harbor bottom sediment and on shoreline mud flat areas uncovered at low tide. However, there had been no increase of harbor water radioactivity in Holy Loch above normal background levels. Joint U.S. and British assessments of survey results confirmed that radiation levels in the vicinity of the Holy Loch anchorage were far below those which were at all likely to cause an individual to receive radiation exposure approaching limits for members of the general public. Environmental monitoring during 1966 showed radioactivity levels in Holy Loch are steadily declining.

REFERENCE

(*1*) VAUGHAN, J. W. and M. E. MILES. Disposal of radioactive wastes from U.S. Naval nuclear-powered ships and their support facilities. Radiol Health Data Rep 7:257–262 (May 1966).

SECTION I. MILK AND FOOD

In the determination of the internal exposure to man from environmental radiation sources, primary interest centers on radionuclides in the diet. Federal and State agencies are involved in efforts to monitor continuously the dietary intake of radionuclides. The most direct measure of radionuclide intake would be obtained through radioanalysis of the total diet. Difficulties in obtaining specific dietary data impede this approach. An alternate method entails the use of indicator foods to arrive at an estimate of the total dietary radionuclide intake.

Fresh milk is one such indicator food. It is consumed by a large segment of the U.S. population and contains most of the biologically significant radionuclides which appear in the diet. It also is one of the major sources of dietary intake for the short-lived radionuclides. For these reasons, fresh milk is the single food item most often used in estimating the intake of selected radionuclides by the general population and/or specific population groups. In the absence of specific dietary information, it is possible to approximate the total daily dietary intake of selected radionuclides as being equivalent to the intake represented by the consumption of 1 liter of fresh milk.

The Federal Radiation Council (FRC) has developed Radiation Protection Guides (RPG's) for controlling normal peacetime nuclear operations, assuming continuous exposure from intake by the population at large (*1–3*). The RPG's do not and cannot establish a line which is safe on one side and unsafe on the other; they do provide an indication of when there is a need to initiate careful evaluation of exposure (*3*). Additional guidelines are provided by the FRC Protective Action Guides (*4*) and by the International Commission on Radiological Protection (*5,6*).

Data from selected national, international, and State milk and food surveillance activities are presented herein. An effort has been made to present a cross-section of routine sampling programs which may be considered of a continuing nature. Routine milk sampling has been defined as one or more samples collected per month.

REFERENCES

(*1*) FEDERAL RADIATION COUNCIL. Background material for the development of radiation protection standards, Report No. 1. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (May 13, 1960).

(*2*) FEDERAL RADIATION COUNCIL. Background material for the development of radiation protection standards, Report No. 2. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (September 1960).

(*3*) FEDERAL RADIATION COUNCIL. Background material for the development of radiation protection standards, protective action for strontium–89, strontium–90, and cesium–137, Report No. 7. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (July 1964).

(*4*) FEDERAL RADIATION COUNCIL. Background material for the development of radiation protection standards, Report No. 5. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (May 1965).

(*5*) INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION. Recommendation of the International Commission on Radiological Protection, Report No. 2. Pergamon Press, New York, N. Y. (1959).

(*6*) INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION. (Recommendation of the International Commission on Radiological Protection, Report No. 6. Pergamon Press, New York, N. Y. (1965).

National and International Milk Surveillance

As part of continuing efforts to quantitatively monitor man's exposure to radionuclides, various national and international organizations routinely monitor radionuclide levels in milk. In addition to those programs reported below, *Radiological Health Data and Reports* coverage includes:

Program	Period reported	Last presented
Radiostrotium in milk, HASL	July–December 1966	September 1967

1. Pasteurized Milk Network August 1967

National Center for Radiological Health and *National Center for Urban and Industrial Health, PHS*

The Public Health Service's Pasteurized Milk Network (PMN) was designed to provide nationwide surveillance of radionuclide concentrations in milk through sampling from major milk production and consumption areas. The present network of 63 stations (figure 1) provides data on milk in every State, the Canal Zone, and Puerto Rico. The most recent description of the sampling and analytical procedures employed by the PMN appeared in the December 1966 issue of *Radiological Health Data and Reports* (*1*).

Table 1. Analytical errors associated with determinations of radionuclide concentrations in milk

Nuclide	Concentration (pCi/liter)	Error [a] (pCi/liter)	Concentration (pCi/liter)	Error [a] (percent of concentration)
Strontium-89	< 50	5	≥ 50	10
Strontium-90	< 20	2	≥ 20	10
Iodine-131	<100	10	≥100	10
Cesium-137	<100	10	≥100	10
Barium-140	<100	10	≥100	10

[a] Two standard deviations.

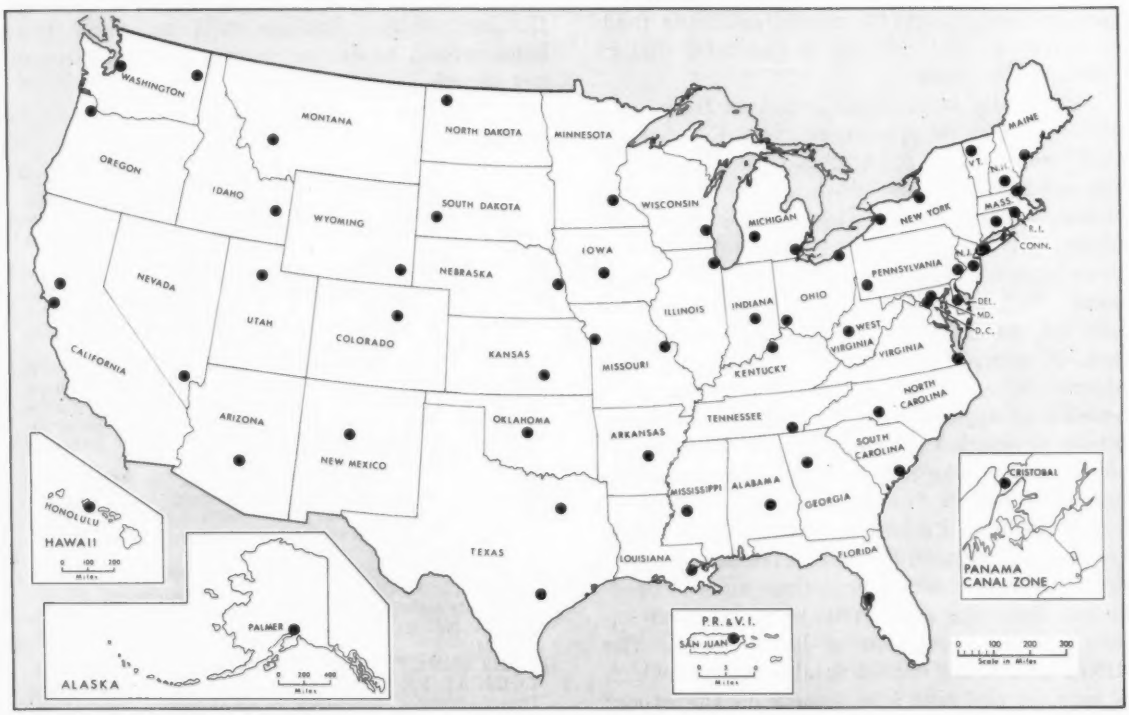

Figure 1. Pasteurized Milk Network sampling stations

Table 2. Average concentrations of radionuclides in pasteurized milk for the second quarter 1967 and August 1967 [a]

Sampling location		Strontium-89 [b] (pCi/liter)		Strontium-90 (pCi/liter)		Cesium-137 (pCi/liter)	
		Second quarter 1967	August 1967	Second quarter 1967	August 1967	Second quarter 1967	August 1967
Ala:	Montgomery	< 5	< 5	10	9	15	20
Alaska:	Palmer	< 5	< 5	7	6	20	25
Ariz:	Phoenix	< 5	< 5	4	1	< 5	< 5
Ark:	Little Rock	< 5	< 5	27	22	20	20
Calif:	Sacramento	10	< 5	5	2	10	5
	San Francisco	10	< 5	5	3	10	< 5
C.Z:	Cristobal	< 5	< 5	5	4	30	20
Colo:	Denver	< 5	< 5	6	6	10	10
Conn:	Hartford			9	10	20	20
Del:	Wilmington			12	10	15	15
D.C:	Washington	< 5	< 5	10	10	15	15
Fla:	Tampa	< 5	< 5	9	8	75	85
Ga:	Atlanta	< 5	< 5	17	16	25	25
Hawaii:	Honolulu	< 5	< 5	4	4	10	15
Idaho:	Idaho Falls	< 5	< 5	7	7	10	15
Ill:	Chicago	< 5	< 5	10	7	15	15
Ind:	Indianapolis			10	8	15	5
Iowa:	Des Moines	< 5	< 5	9	8	15	10
Kans:	Wichita	5	< 5	8	8	10	10
Ky:	Louisville	< 5	< 5	15	14	10	10
La:	New Orleans	< 5	< 5	28	22	30	25
Maine:	Portland			12	12	35	40
Md:	Baltimore	< 5	< 5	13	10	20	10
Mass:	Boston	< 5	< 5	12	13	35	30
Mich:	Detroit			9	8	15	15
	Grand Rapids			11	10	25	15
Minn:	Minneapolis	< 5	< 5	14	13	20	20
Miss:	Jackson	< 5	< 5	21	17	20	15
Mo:	Kansas City	5	< 5	10	10	10	5
	St. Louis	5	< 5	10	10	10	10
Mont:	Helena	< 5	< 5	6	6	10	10
Nebr:	Omaha	< 5	< 5	8	9	10	15
Nev:	Las Vegas	< 5	< 5	2	3	5	5
N.H:	Manchester			15	13	50	50
N.J:	Trenton			10	9	20	10
N. Mex:	Albuquerque	< 5	< 5	3	3	< 5	15
N.Y:	Buffalo			9	7	20	15
	New York			12	9	20	20
	Syracuse			9	10	20	15
N.C:	Charlotte	< 5	< 5	19	17	20	15
N. Dak:	Minot	5	< 5	17	10	25	10
Ohio:	Cincinnati			11	8	15	5
	Cleveland			11	9	20	15
Okla:	Oklahoma City	< 5	< 5	12	9	10	5
Ore:	Portland	5	< 5	10	6	20	15
Pa:	Philadelphia			10	9	15	10
	Pittsburgh			15	13	25	15
P.R:	San Juan	< 5	< 5	4	5	15	10
R.I:	Providence			11	12	25	25
S.C:	Charleston	< 5	< 5	16	16	35	30
S. Dak:	Rapid City	5	< 5	14	14	15	15
Tenn:	Chattanooga	< 5	< 5	17	15	20	15
	Memphis	< 5	< 5	16	13	10	10
Tex:	Austin	< 5	< 5	4	2	10	10
	Dallas	< 5	< 5	12	7	15	10
Utah:	Salt Lake City	< 5	< 5	6	6	15	15
Vt:	Burlington			11	10	25	20
Va:	Norfolk	< 5	< 5	14	13	15	15
Wash:	Seattle	5	< 5	12	7	35	35
	Spokane	< 5	< 5	12	7	20	20
W. Va:	Charleston	< 5	< 5	15	11	15	10
Wisc:	Milwaukee			7	7	20	15
Wyo:	Laramie	< 5	< 5	5	4	10	10
Network average		< 5	< 5	11	9	20	15

[a] Iodine-131 and barium-140 concentrations for all stations were below the limits of detectability.
[b] Blank indicates no strontium-89 determinations were made on samples from station during month.

Table 1 shows the approximate analytical errors (including counting error) associated with determinations of radionuclide concentrations in milk. These errors were determined by comparing results of a large number of replicate analyses. The minimum detectable concentration is defined as the measured concentration equal to the two-standard deviation analytical error. Accordingly, the minimum detectable concentrations in units of pCi/liter are: strontium–89, 5; strontium–90, 2; cesium–137, 10; barium–140, 10; and iodine–131, 10. At these levels and below, the counting error comprises nearly all of the analytical error. The results for August 1967, and the second quarter of 1967, are presented in table 2. The average monthly radionuclide concentrations are based on results obtained from samples collected weekly. If radionuclide values were below minimum detectable concentrations, averages were calculated using one-half the minimum detectable values; however, for iodine–131 and barium–140, zero was used for averaging purposes when concentrations were below minimum detectable levels. Because all values for iodine–131 and barium–140 were below minimum detectable concentrations during the period covered in this report, results for these two radionuclides have not been included in table 2.

For comparative purposes, distributions of strontium–90 and cesium–137 are presented in

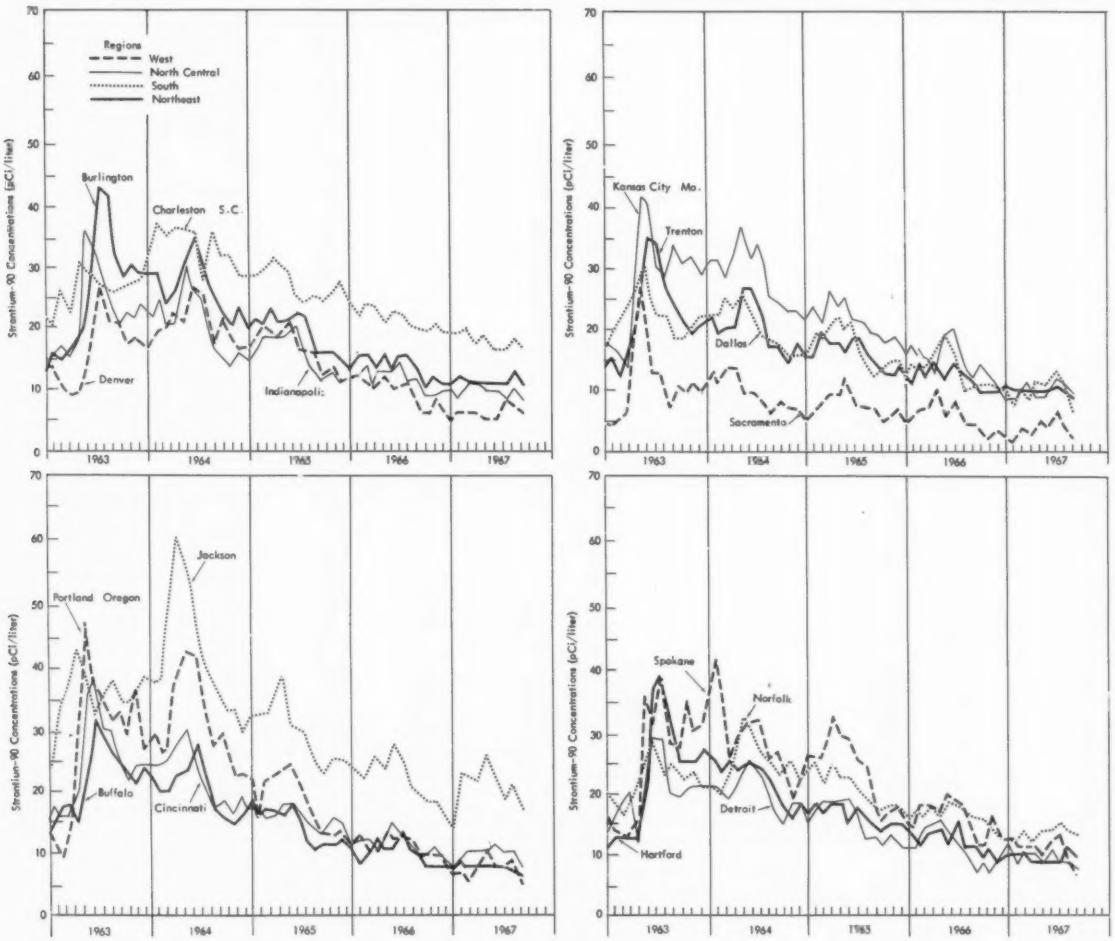

Figure 2. Strontium–90 concentrations in pasteurized milk, 1961–August 1967

tables 3 and 4 for August 1966, and March through August 1967. The average strontium–90 concentrations in pasteurized milk from selected cities are presented in figure 2.

Table 3. Frequency distribution, strontium-90 concentrations in milk at PMN stations, August 1966, March-August 1967

Strontium-90 (pCi/liter)	Number of stations *						
	1966	1967					
	August	March	April	May	June	July	August
Under 10	15 (24)	25 (40)	25 (40)	25 (40)	27 (43)	25 (40)	35 (55)
10–19	40 (63)	35 (55)	34 (54)	35 (55)	34 (54)	35 (55)	26 (42)
20–29	7 (11)	2 (3)	4 (6)	3 (5)	2 (3)	3 (5)	2 (3)
30–39	1 (2)	1 (2)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)

* Percentage of stations shown in parentheses.

Table 4. Frequency distribution, cesium-137 concentrations in milk at PMN stations, August 1966, March-August 1967

Cesium-137 (pCi/liter)	Number of stations *						
	1966	1967					
	August	March	April	May	June	July	August
Under 50	56 (89)	62 (98)	62 (98)	61 (97)	61 (97)	61 (97)	61 (97)
50–99	6 (9)	1 (2)	1 (2)	2 (3)	2 (3)	2 (3)	2 (3)
100–149	1 (2)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)

* Percentage of stations shown in parentheses.

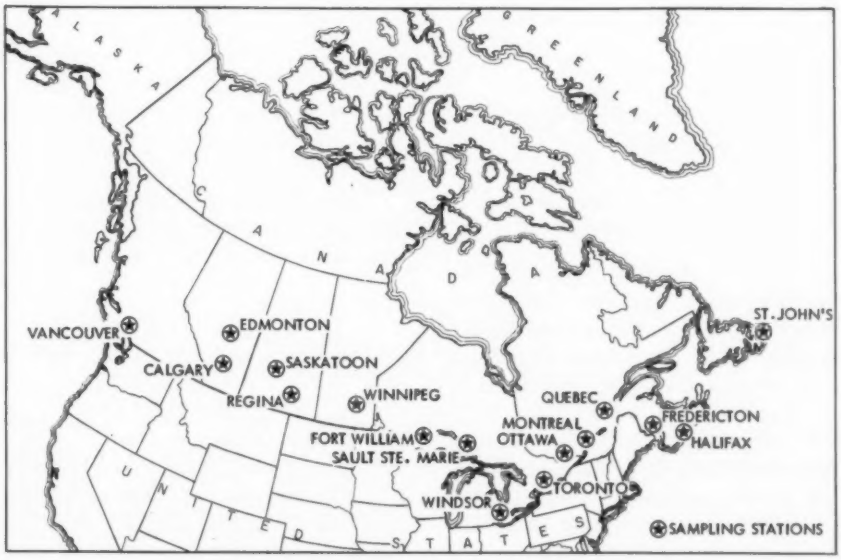

Figure 3. Canadian milk sampling stations

2. Canadian Milk Network August 1967 [1]

Radiation Protection Division, Department of National Health and Welfare

Since November 1955, the Radiation Protection Division of the Department of National Health and Welfare has been monitoring milk for radionuclide concentrations. Powdered milk was originally sampled, but liquid whole milk has been sampled since January 1963. At present, 16 milk sampling stations (figure 3) are in operation. Their locations coincide with air and precipitation sampling stations.

Milk samples are collected three times a week from selected dairies and are combined into weekly composites. The contribution of each dairy to the composite sample is directly proportional to the liquid volume of sales. Weekly spot check analyses are made for iodine–131, and monthly composites are analyzed for strontium–90, cesium–137, and stable calcium and potassium. The analytical procedures were outlined in the December 1966 issue of *Radiological Health Data and Reports* (*2*).

The August 1967 monthly average strontium–90, cesium–137, and stable calcium and potassium concentrations in Canadian whole milk are presented in table 5. Iodine–131 and strontium–89 concentrations were below minimum detectable levels.

[1] Prepared from September 1967 monthly report, "Data from Radiation Protection Programs," Canadian Department of National Health and Welfare, Ottawa, Canada.

Table 5. Stable elements and radionuclides in Canadian whole milk, August 1967

Station	Calcium (g/liter)	Potassium (g/liter)	Strontium-90 (pCi/liter)	Cesium-137 (pCi/liter)
Calgary	1.13	1.4	11	20
Edmonton	1.09	1.4	8	28
Ft. William	1.06	1.5	15	32
Fredericton	1.06	1.5	17	38
Halifax	1.11	1.6	17	32
Montreal	1.07	1.6	9	26
Ottawa	1.09	1.6	8	21
Quebec	1.06	1.5	15	32
Regina	1.07	1.4	7	16
St. John's, Nfld	1.12	1.5	32	110
Saskatoon	1.09	1.5	8	23
Sault Ste. Marie	1.08	1.5	17	43
Toronto	1.10	1.5	4	17
Vancouver	1.15	1.5	15	50
Windsor	1.10	1.5	5	13
Winnipeg	1.14	1.6	8	25
Average	1.10	1.5	12	33

3. Pan American Milk Sampling Program August 1967

Pan American Health Organization and *U.S. Public Health Service*

The Pan American Health Organization (PAHO), in collaboration with the U.S. Public Health Service (PHS), furnishes assistance to health agencies in the American Republics in developing national radiological health programs.

Under a joint agreement between agencies, air and milk sampling activities are conducted by a number of PAHO member countries (figure 4). Results of the milk sampling program are presented below. Further information on the sampling and analytical procedures employed was presented in the December 1966 issue of *Radiological Health Data and Reports* (*3*).

Table 6 presents stable potassium, strontium–89, strontium–90, and cesium–137, monthly average concentrations for August 1967.

REFERENCES

(*1*) PUBLIC HEALTH SERVICE. Pasteurized Milk Network, August 1966. Radiol Health Data Rep 7:698–701 (December 1966).

(*2*) DEPARTMENT OF NATIONAL HEALTH AND WELFARE, RADIATION PROTECTION DIVISION. Canadian milk network, August 1966. Radiol Health Data Rep 7:702–703 (December 1966).

(*3*) PAN AMERICAN HEALTH ORGANIZATION and U.S. PUBLIC HEALTH SERVICE. Pan American Milk Sampling Program, August 1966. Radiol Health Data Rep 7:704–705 (December 1966).

Figure 4. Pan American Milk Sampling Program stations

Table 6. Stable element and radionuclide concentration in PAHO milk [a] August 1967

Sampling stations	Number of samples	Potassium (g/liter)	Strontium-89 (pCi/liter)	Strontium-90 (pCi/liter)	Cesium-137 (pCi/liter)
Chile: Santiago	5	1.6	6	3	12
Colombia: Bogota	1	1.5	5	3	< 5
Ecuador: Guayaquil	1	1.7	5	<1	5
Jamaica: Mandeville	1	1.4	5	5	130
Canal Zone: Cristobal [b]	5	----------	<5	4	20
Puerto Rico: San Juan [b]	5	----------	<5	5	10

[a] Iodine-131 and barium-140 determinations were less than 10 pCi/liter for all samples.
[b] For comparison purposes, the radionuclide concentrations at Cristobal, Canal Zone and San Juan, Puerto Rico, from the Pasteurized Milk Network are presented.

State Milk Surveillance Activities

Considerable progress has been made by the State health departments in initiating or expanding environmental surveillance activities in radiological health. Many of the States have reached a point of having comprehensive environmental surveillance programs and self-sustaining radiological health laboratories.

The continuing efforts of State health departments in the analysis and monitoring of radionuclides in milk complement Federal milk surveillance activities. State milk surveillance activities are continually undergoing developmental changes at this time. The results presented herein are representative of current sur-

veillance activities directed at the use of milk as an indicator of dietary intake of radioactivity.

Figure 1 shows those States which report milk surveillance activities in *Radiological Health Data and Reports*. States having programs appearing in this issue are highlighted in the figure. A summary of State programs previously covered, the reporting period, and issue of appearance is as follows.

State milk network	Period reported	Last presented
Colorado	April–June 1967	October 1967
Connecticut	April–June 1967	November 1967
Florida	April–June 1967	October 1967
Indiana	April–June 1967	November 1967
Iowa	April–June 1967	November 1967
Michigan	April–June 1967	November 1967
Minnesota	April–June 1967	November 1967
New York	April–June 1967	November 1967
Oklahoma	April–June 1967	October 1967
Pennsylvania	April–June 1967	November 1967
Tennessee	April–June 1967	October 1967
Texas	April–June 1967	October 1967

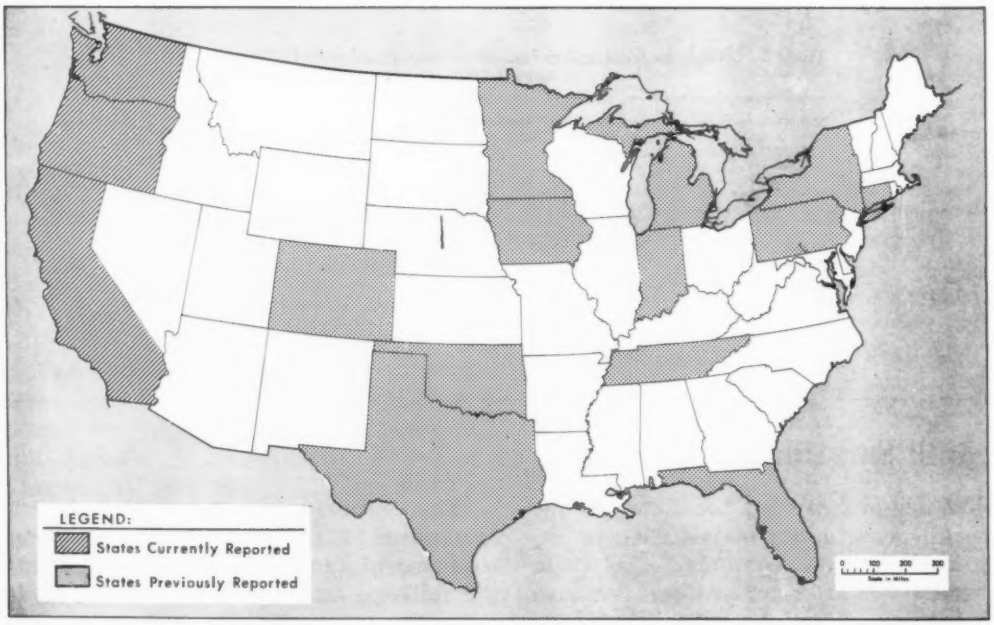

Figure 1. Reported State milk programs

1. California Milk Network April–June 1967

Division of Environmental Sanitation, State of California, Department of Public Health

Surveillance of specific radionuclides in milk is one phase of the California Department of Health program on radiation control. This milk monitoring function is conducted by the Department's Bureau of Radiological Health at 10 major milksheds (figure 2).

In January 1960, the eight original sampling locations were chosen by the State Department of Agriculture so as to be representative of milk consumed by a high percentage of the State's population. The Del Norte and Mendocino milksheds were added to the program in March 1962 and since that time weekly, biweekly or monthly sampling of pasteurized milk has been conducted in 10 milkshed areas of the State. A description of the various California milksheds was presented earlier by Heslep and Cornish (*1*).

Strontium–89 and strontium–90 concentrations are determined radiochemically. Potassium–40, iodine-131, cesium–137, and barium–140 in whole fluid milk are determined by gamma-scintillation spectrometry. A detailed description of the analytical procedures was presented in an earlier report (*2*).

The monthly calcium and radionuclide concentrations in California pasteurized milk are given in table 1 for the period of April to June 1967. Iodine–131 was below the detectable limit for all stations for this period.

Network average strontium–90 and cesium–137 concentrations are presented graphically in figure 3.

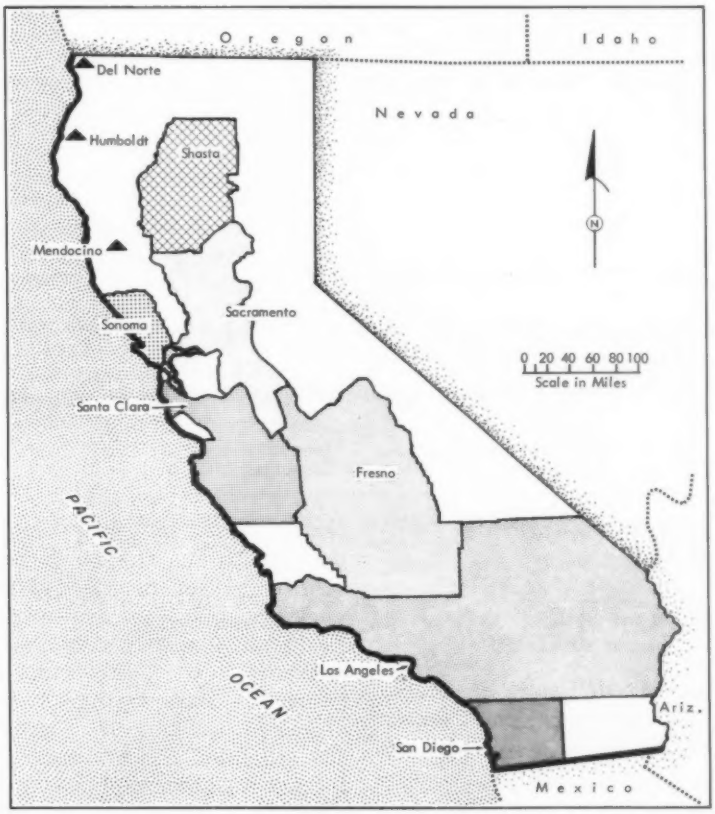

Figure 2. California milksheds

Table 1. Stable element and radionuclides in California milk, April-June 1967

Sampling location	Calcium (g/liter)			Potassium-40 (pCi/liter)			Strontium-89 (pCi/liter)			Strontium-90 (pCi/liter)			Cesium-137 (pCi/liter)			Barium-140 (pCi/liter)		
	April	May	June	April	May	June	April	May	June	April	May	June	April	May	June	April	May	June
Del Norte	1.23	1.34	1.06	1,127	1,080	1,120	53	27	9	26	25	23	46	36	33	30	29	ND
Fresno	1.17	1.19	1.32	1,141	1,157	1,102	2	4	ND	2	3	9	11	13	12	31	19	ND
Humboldt	1.22	1.30	1.15	1,133	1,143	1,092	22	16	3	8	3	8	16	21	13	18	26	ND
Los Angeles	1.04	1.11	1.10	1,264	1,261	1,170	ND	2	[a]1	2	2	2	7	10	11	6	27	ND
Mendocino	1.20	1.11	1.11	1,176	1,155	1,099	12	9	3	5	10	6	16	14	16	39	29	ND
Sacramento	1.21	1.24	1.03	1,087	1,120	NA	10	7	[a]1	4	5	4	21	15	NA	45	25	ND
San Diego	1.15	1.10	1.14	1,310	1,159	1,075	ND	[a]1	ND	2	2	2	[a]5	[a]7	[a]7	[a]6	18	ND
Santa Clara	1.15	1.13	1.16	1,194	1,120	1,089	[a]1	ND	[a]2	2	8	4	6	16	15	[a]1	28	ND
Shasta	1.11	1.15	1.16	1,118	NA	1,080	4	9	2	4	4	5	18	NA	13	22	NA	[a]30
Sonoma	1.20	1.12	1.18	1,203	1,098	1,115	14	6	4	5	9	7	25	16	17	45	30	ND
Average	1.17	1.18	1.14	1,175	1,143	1,105	12	8	3	6	7	7	17	15	14	24	26	3

[a] When the counting rate of the sample is not equal to at least twice the 0.95 error, the value reported is the best available estimate, but is not statistically significant.
ND, nondetectable.
NA, no analysis.

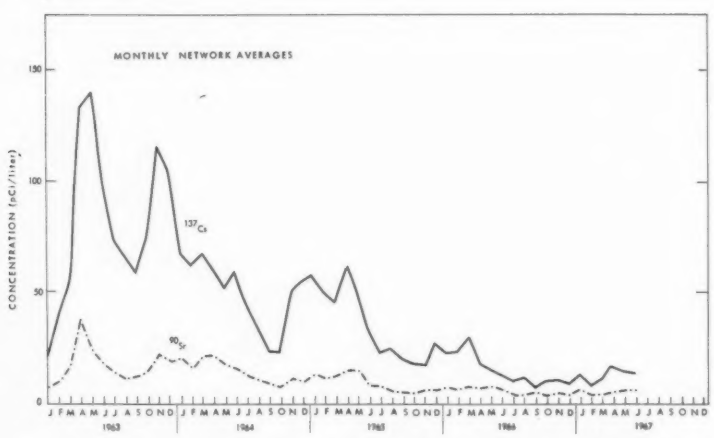
MONTHLY NETWORK AVERAGES
CONCENTRATION (pCi/liter)
150
100
50
0
137Cs
90Sr
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1963
1964
1965
1966
1967

Figure 3. Radionuclide concentrations in California milk, 1963–June 1967

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
October–December 1966	June 1967
January–March 1967	September 1967

2. Oregon Milk Network April–June 1967

Division of Sanitation and Engineering
Oregon State Board of Health

The Oregon State Board of Health has monitored radionuclide concentrations in milk since March 1962. As part of this program routine milk samples are collected at seven major production areas (figure 4), which supply 90 percent of the milk distributed in Oregon. Currently, pasteurized milk samples are collected monthly by the Oregon Department of Agriculture, except in the Portland area where weekly samples are collected by the city of Portland. The milk sampling frequency is accelerated to a weekly basis in areas where iodine–131 concentrations exceed 100 pCi/liter, or when cesium–137 concentrations exceed 500 pCi/liter. Strontium–90 analyses are performed on a bimonthly basis, but may be done monthly when significant increases are observed.

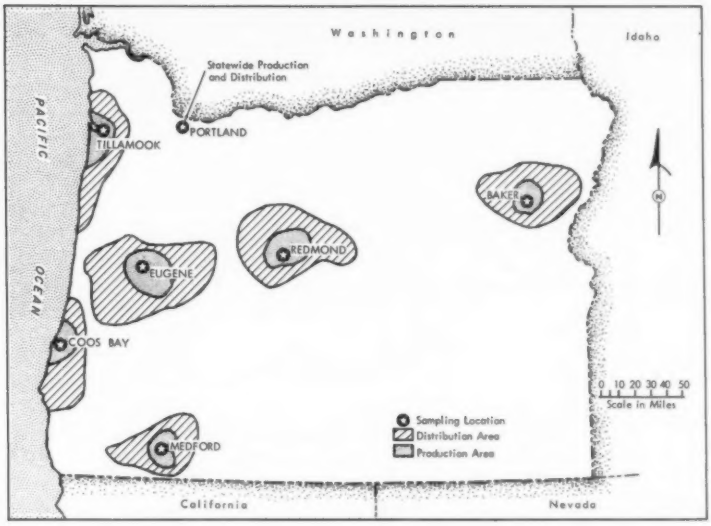

Figure 4. Oregon milk production and distribution areas

Strontium–90 concentrations are determined using a trichloroacetic acid analytical procedure (*3*). Iodine–131, cesium–137, and barium–140 concentrations are determined by gamma-scintillation spectrometry (*4*).

Table 2 gives the strontium–90 and cesium–137 concentrations in pasteurized milk from April through June 1967. These data are presented graphically in figure 5. Iodine–131 and barium–140 concentrations remained below minimum detectable levels of 15 pCi/liter for all samples which were collected in April through June 1967. Anticipated increases of radioactivity in milk from the Chinese nuclear test on June 17, 1967, were not observed during this period.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
October–December 1966	June 1967
January–March 1967	September 1967

Table 2. Radionuclide concentrations in Oregon pasteurized milk, April-June 1967

Location	Sampling frequency [a]	Strontium-90 (pCi/liter)			Cesium-137 (pCi/liter)		
		April	May	June	April	May	June
Baker	M	NS	10	NS	<15	15	<15
Coos Bay	M	NS	17	NS	26	25	43
Eugene	M	NS	14	NS	16	20	18
Medford	M	NS	8	NS	<15	<15	56
Portland composite	W	11	8	8	38	22	18
Portland local	W	NS	19	NS	35	35	35
Redmond	M	NS	8	NS	NS	20	31
Tillamook	M	NS	NS	NS	23	NS	118
Average		11	12	8	24	22	42

[a] M, sampled monthly, W, sampled weekly.
NS, no sample collected.

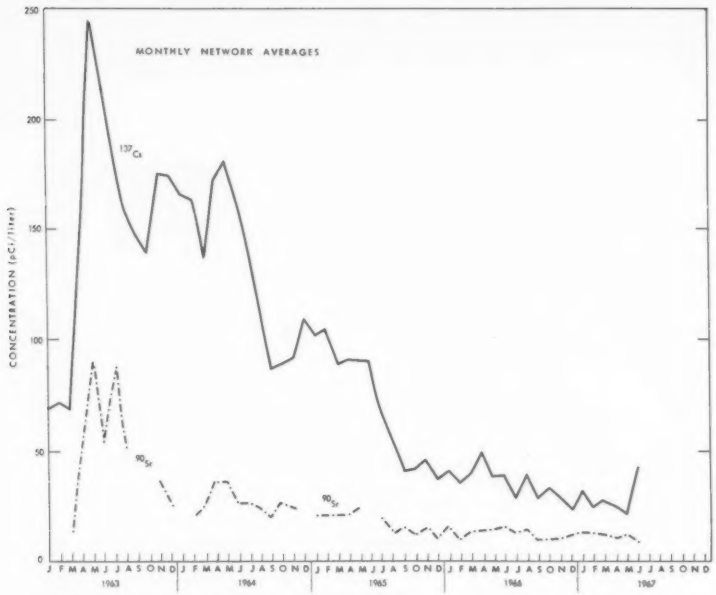
MONTHLY NETWORK AVERAGES
CONCENTRATION (pCi/liter)
250
200
150
100
50
0
^{137}Cs
^{90}Sr
^{90}Sr
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1963
1964
1965
1966
1967

Figure 5. Radionuclide concentrations in Oregon milk network 1963–June 1967

3. Washington Milk Network April–June 1967

Air Quality and Radiation Control Section
State of Washington Department of Health

The Washington State Department of Health initiated a surveillance program for radioactivity in raw milk in December 1962. The collection points shown in figure 6 were selected to provide samples representative of varying climatological conditions within the State's two major milksheds. In addition to the eight milk sampling locations in Washington, milk is sampled from Northwest Idaho (Sandpoint), as this area forms a part of the Spokane milkshed. Details of the sampling procedures were presented in an earlier report (*5*).

Selected samples are analyzed radiochemically for strontium–90. Potassium–40, iodine–131, cesium–137, and barium–140 concentrations are determined by gamma scintillation spectrometry. Details of the analytical procedures were presented earlier (*5*).

Table 3 presents monthly radionuclide concentrations in Washington raw milk for April through June 1967. Samples collected during April through June 1967 contained less than 10 pCi/liter of iodine–131. Barium–140 results remained below 15 pCi/liter for all samples collected during this period. Monthly average strontium–90 and cesium–137 concentrations are presented graphically in figure 7 to display general trends.

During this reporting period, three samples were collected (one from Benton County and two from Franklin County) and analyzed for zinc–65. In all three cases, zinc–65 levels were less than 25 pCi/liter. Milk samples produced in areas using Columbia River water for irrigation have periodically been found to contain this radionuclide.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
October–December 1966	June 1967
January–March 1967	September 1967

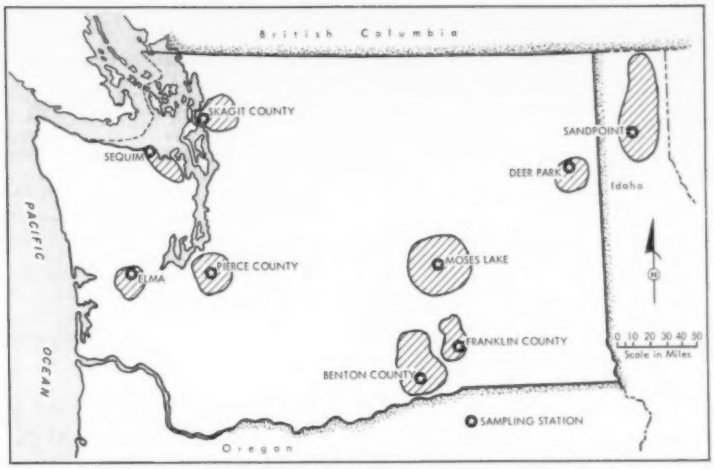

Figure 6. Washington milksheds and sampling locations

Table 3. Radionuclide concentrations in Washington raw milk, April-June 1967

Sampling location	Potassium-40 (pCi/liter)			Strontium-90 (pCi/liter)			Cesium-137 (pCi/liter)		
	April	May	June	April	May	June	April	May	June
Benton County	NS	1,230	NS	NS	6	NS	NS	<15	NS
Deer Park	1,200	1,190	*1,110	10	10	13	26	20	*25
Elma	1,180	1,180	*1,175	6	13	9	22	64	*26
Franklin County	1,210	NS	1,160	4	NS	2	<15	NS	<15
Moses Lake	1,260	1,250	*1,250	5	6	5	15	<15	*<15
Pierce County	1,110	1,210	*1,225	5	16	12	15	46	*28
Sandpoint, Idaho	1,280	1,260	*1,215	24	23	12	38	39	*39
Sequim	1,160	1,180	1,200	9	9	8	26	20	21
Skagit County	1,160	1,130	*1,220	9	16	15	21	27	*22
Average	1,195	1,205	1,195	9	12	10	22	31	24

* Represents an average of two samples collected at these sampling locations during the month.
NS, no sample collected.

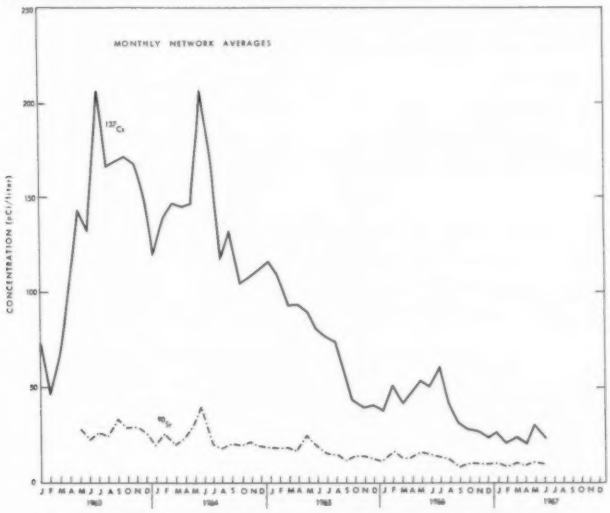
MONTHLY NETWORK AVERAGES
CONCENTRATION (pCi/liter)
137Cs
90Sr
250
200
150
100
50
0
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1963
1964
1965
1966
1967

Figure 7. Radionuclide concentrations in Washington milk 1963–June 1967

REFERENCES

(1) HESLEP, J. M. and A. C. CORNISH. California milk network and milkshed comparisons, April-June 1963. Radiol Health Data 4:596–599 (December (1963).

(2) STATE OF CALIFORNIA DEPARTMENT OF PUBLIC HEALTH. California milk network, 1960–June 1962.) Radiol Health Data 4:90–92 (February 1963).

(3) MURTHY, G. K., J. E. COAKLEY, and J. E. CAMPBELL. A method for the elimination of ashing in strontium-90 determinations in milk. J Dairy Sci 43:151–154 (1960).

(4) OREGON STATE BOARD OF HEALTH, DIVISION OF SANITATION AND ENGINEERING. Oregon milk network, April-June 1965. Radiol Health Data 6:683–684 (December 1965).

(5) STATE OF WASHINGTON DEPARTMENT OF HEALTH, AIR, SANITATION AND RADIATION CONTROL SECTION. Washington milk network, January-June 1965. Radiol Health Data 6:619–621 (November 1965).

Food and Diet Surveillance

Efforts are being made by various Federal and State agencies to estimate the dietary intake of selected radionuclides on a continuing basis. These estimates along with the guidance developed by the Federal Radiation Council, provide a basis for evaluating the significance of radioactivity in foods and diet.

Networks presently in operation and reported routinely include those listed below. These networks provide data useful for developing estimates of nationwide dietary intakes of radionuclides. Periodically, results from the United Kingdom Diet Survey conducted by the United Kingdom Agricultural Research Council Radiobiological Laboratory, are presented for comparison with data observed in the United States. The most recent reports on these programs in *Radiological Health Data and Reports* are as follows.

Program	Period reported	Last presented
California Diet Study	January–February 1967	October 1967
Connecticut Standard Diet	January–June 1967	November 1967
Institutional Diet, PHS	January–March 1967 and annual summary 1966	October 1967
Teenage Diet, FDA	February–November 1965	August 1966
Tri-City Diet, HASL	August–December 1966	September 1967
United Kingdom Diet, ARCRL	Annual summary 1965	December 1966

SECTION II. WATER

The Public Health Service, the Federal Water Pollution Control Administration and other Federal, State, and local agencies operate extensive water quality sampling and analysis programs for surface, ground, and treated water. Most of these programs include determinations of gross beta and gross alpha radioactivity and specific radionuclides.

Although the determination of the total radionuclide intake from all sources is of primary importance, a measure of the public health importance of radioactivity levels in water can be obtained by comparison of the observed values with the Public Health Service Drinking Water Standards (*1*). These standards, based on consideration of Federal Radiation Council (FRC) recommendations (*2–4*), set the limits for approval of a drinking water supply containing radium–226 and strontium–90 as 3 pCi/liter and 10 pCi/liter, respectively. Limits may be set higher if the total intake of radioactivity from all sources remains within the guides recommended by FRC for control action. In the known absence of strontium–90 and alpha-particle emitters, the limit is 1,000 pCi/liter gross beta radioactivity, except when additional analysis indicates that concentrations of radionuclides are not likely to cause exposures greater than the limits indicated by the Radiation Protection Guides. Surveillance data from a number of Federal and State programs are published periodically to show current and long-range trends. Water sampling activities recently reported in *Radiological Health Data and Reports* are listed below.

[1] Absence is taken to mean a negligibly small fraction of the specific limits of 3 pCi/liter and 10 pCi/liter for unidentified alpha-particle emitters and strontium–90, respectively.

Activity	Period reported	Last presented
California Water Sampling Program	January–June 1966	June 1967
Coast Guard Water Sampling Program	1966	November 1967
Minnesota Surface Water Sampling Program	January–June 1966	January 1967
New York Surface Water Sampling Program	January–December 1966	September 1967
Radiostrontium in Tap Water, HASL	March–November 1966	June 1967
Washington Surface Water Sampling Program	July 1965–June 1966	August 1967

REFERENCES

(*1*) U.S. PUBLIC HEALTH SERVICE. Drinking water standards, revised 1962, PHS Publication No. 956. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (March 1963).

(*2*) FEDERAL RADIATION COUNCIL. Radiation Protection Guidance for Federal Agencies. Memorandum for the President, September 1961. Reprint from the Federal Register of September 26, 1961.

(*3*) FEDERAL RADIATION COUNCIL. Background material for the development of Radiation Protection Standards, Report No. 1. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (May 1960).

(*4*) FEDERAL RADIATION COUNCIL. Background material for the development of Radiation Protection Standards, Report No. 2. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (September 1961).

Gross Radioactivity in Surface Waters of the United States, June 1967

Division of Pollution Surveillance, Federal Water Pollution Control Administration, Department of Interior

The monitoring of levels of radioactivity in surface waters of the United States was begun in 1957 as part of the Federal Water Pollution Control Administration's Water Pollution Surveillance System. Table 1 presents the current preliminary results of the alpha- and beta-particle analyses. The radioactivity associated with dissolved solids provides a rough indication of the levels which would occur in treated water, since nearly all suspended matter is removed by treatment processes. Strontium–90 results are reported semiannually. The stations on each river are arranged in the table according to their distance from the headwaters. Figure 1 indicates the average total beta radioactivity in suspended-plus-dissolved solids in raw water collected at each station. A description of the sampling and analytical procedures was published in the August 1967 issue of *Radiological Health Data and Reports.*

Complete data and exact sampling locations for 1958 through 1963 are published in annual compilations (*1–6*). Data for subsequent years are available on request.

Special note is taken when the alpha radioactivity is 15 pCi/liter or greater or when the beta radioactivity is 150 pCi/liter or greater. These arbitrary levels provide a basis for the selection of certain data for comment. They reflect no public health significance as the Public Health Service drinking water standards have already provided the basis for this assessment. Changes from or toward these arbitrary levels are also noted in terms of changes in radioactivity per unit weight of solids. No discussion of gross radioactivity per gram of

Figure 1. Sampling locations and associated total gross beta radioactivity (pCi/liter) for surface waters, June 1967

Table 1. Radioactivity in raw surface waters, June 1967

Station	Average alpha radioactivity (pCi/liter)			Average beta radioactivity (pCi/liter)		
	Suspended	Dissolved	Total	Suspended	Dissolved	Total
Animas River:						
Cedar Hill, N. Mex.	1	1	2	7	5	12
Arkansas River:						
Coolidge, Kans.	9	10	19	38	37	75
Ponca City, Okla.	17	2	19	57	13	70
Atchafalaya River:						
Morgan City La.	3	0	3	24	7	31
Bear River:						
Preston, Idaho	1	1	2	5	21	26
Big Horn River:						
Hardin, Mont.	5	10	15	20	16	36
Big Sioux River:						
Sioux Falls, S. Dak.	2	< 1	2	20	17	37
Clearwater River:						
Lewiston, Idaho	< 1	0	< 1	2	3	5
Clinch River:						
Clinton, Tenn.	0	1	1	1	3	4
Kingston, Tenn.[a]	0	0	0	< 1	15	15
Colorado River:						
Page, Ariz.	0	12	12	2	20	22
Columbia River:						
Wenatchee, Wash.	0	0	0	0	3	3
Pasco, Wash.[a]	0	0	0	22	58	80
Clatskanie, Ore.	< 1	0	< 1	20	25	45
Connecticut River:						
Enfield Dam, Conn.	0	0	0	1	3	4
Coosa River:						
Rome, Ga.	< 1	1	1	1	6	7
Cumberland River:						
Cheatham Lock, Tenn.	0	0	0	1	3	4
Delaware River:						
Philadelphia, Pa.	0	0	0	1	3	4
Great Lakes:						
Duluth, Minn.	0	0	0	1	2	3
Green River:						
Dutch John, Utah	< 1	2	2	1	13	14
Hudson River:						
Poughkeepsie, N. Y.	0	0	0	2	5	7
Illinois River:						
Peoria, Ill.	2	1	3	6	9	15
Grafton, Ill.	0	2	2	2	10	12
Kansas River:						
DeSoto, Kans.	17	1	18	64	9	73
Klamath River:						
Keno, Ore.	0	0	0	1	6	7
Maumee River:						
Toledo, Ohio	0	2	2	1	10	11
Mississippi River:						
St. Paul, Minn.	0	1	1	1	11	12
E. St. Louis, Ill.	12	1	13	30	11	41
New Roads, La.	3	0	3	10	8	18
New Orleans, La.	6	2	8	14	11	25
Missouri River:						
Williston, N. Dak.	6	2	8	29	10	39
Bismarck, N. Dak.	2	4	6	10	17	27
St. Joseph, Mo.	16	3	19	37	17	54
North Platte River:						
Henry, Nebr.	4	8	12	20	25	45
Ohio River:						
Toronto, Ohio	0	0	0	1	7	8
Cairo, Ill.	1	1	2	2	6	8
Pend Oreille River:						
Albeni Falls Dam, Idaho	0	0	0	1	3	4
Platte River:						
Plattsmouth, Nebr.	54	2	56	214	15	229
Potomac River:						
Washington, D.C.	0	0	0	0	3	3
Rainy River:						
Baudette, Minn.	0	0	0	1	10	11
Red River, North:						
Grand Forks, N.Dak.	4	2	6	10	18	28
Red River, South:						
Alexandria, La.	4	0	4	17	9	26
Rio Grande:						
El Paso, Tex.	4	3	7	16	16	32
Laredo, Tex.	1		6	5	18	23
San Joaquin River:						
Vernalis, Calif.	1	0	1	3	3	6
San Juan River:						
Shiprock, N. Mex.	597	5	602	2,065	15	2,080
Savannah River:						
Port Wentworth, Ga.[a]	< 1	1	1	3	6	9
Snake River:						
Payette, Idaho	< 1	3	3	5	7	12
Wawawai, Wash.	0	0	0	2	2	4
South Platte River:						
Julesburg, Colo.	22	14	36	100	30	130
Susquehanna River:						
Conowingo, Md.	0	0	0	1	4	5
Tennessee River:						
Chattanooga, Tenn.	0	0	0	0	4	4
Yellowstone River:						
Sidney, Mont.	19	6	25	81	8	89
Maximum	597	14	602	2,065	58	2,080
Minimum	0	0	0	0	2	3

[a] Gross beta radioactivity at this station may not be directly comparable to gross beta radioactivity at other stations because of the possible contribution of radionuclides from an upstream nuclear facility in addition to the contribution from fallout and naturally occuring radionuclides.

dissolved or suspended solids for all stations of the Water Pollution Surveillance System will be attempted at this time. Comments are made only on monthly average values. Occasional high values from single weekly samples may be absorbed into a relatively low average. When these values are significantly high, comment will be made.

During both May and June, the following stations showed alpha radioactivity in excess of 15 pCi/liter for either suspended or dissolved solids:

San Juan River; Shiprock, N. Mex.
South Platte River; Julesburg, Colo.
Yellowstone River; Sidney, Mont.

In June, the following stations showed alpha radioactivity in excess of 15 pCi/liter on suspended solids:

Arkansas River; Ponca City, Okla.
Kansas River; DeSoto, Kans.
Missouri River; St. Joseph, Mo.
Platte River; Plattsmouth, Nebr.

Plattsmouth, Nebr. on the Platte River also showed beta radioactivity in excess of 150 pCi/liter on suspended solids.

The following stations decreased to less than 15 pCi/liter alpha radioactivity or 150 pCi/liter beta radioactivity on either suspended or dissolved solids:

Animas River; Cedar Hill, N. Mex.

Arkansas River; Coolidge, Kans.

Columbia River; Pasco, Wash.

Samples collected June 6 and June 21 at Shiprock, N. Mex., on the San Juan River contained beta radioactivity on suspended solids greatly in excess of 150 pCi/liter. This high value is due to the high solids content of these samples. On a weight basis the average values on suspended solids for these sample were 24 pCi/g for alpha radioactivity and 83 pCi/g for beta radioactivity. These values are not significantly different from the values on a weight basis found in the samples collected on June 14 and June 24. These latter samples yielded values on a volume basis (pCi/liter) that are normal for this station.

REFERENCES

(1) PUBLIC HEALTH SERVICE, DIVISION OF WATER SUPPLY AND POLLUTION CONTROL. National water quality network annual compilation of data, PHS publication No. 663, 1958 Edition. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.
(2) *Ibid.*, 1959 Edition.
(3) *Ibid.*, 1960 Edition.
(4) *Ibid.*, 1961 Edition.
(5) *Ibid.*, 1962 Edition.
(6) PUBLIC HEALTH SERVICE, DIVISION OF WATER SUPPLY AND POLLUTION CONTROL. Water pollution surveillance system, annual compilation of data, PHS Publication No. 663 (Revised), 1963 Edition. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

SECTION III. AIR AND DEPOSITION

Radioactivity in Airborne Particulates and Precipitation

Continuous surveillance of radioactivity in air and precipitation provides one of the earliest indications of changes in environmental fission product radioactivity. To date, this surveillance has been confined chiefly to gross beta-particle analysis. Although such data are insufficient to assess total human radiation exposure from fallout, they can be used to determine when to modify monitoring in other phases of the environment.

Surveillance data from a number of programs are published monthly and summarized periodically to show current and long-range trends of atmospheric radioactivity in the Western Hemisphere. These include data from activities of the U.S. Public Health Service, the Canadian Department of National Health and Welfare, the Mexican Commission of Nuclear Energy, and the Pan American Health Organization.

An intercomparison of the above networks was performed by Lockhart and Patterson in 1962 and is summarized in the January 1964 issue of *Radiological Health Data*. In addition to those programs presented in this issue, the folowing programs were previously covered in *Radiological Health Data and Reports.*

Network	Period	Issue
HASL Fallout Network	July–December 1966	September 1967
HASL 80th Meridian Network	Calendar Year 1965	January 1967
Plutonium in Airborne Particulates	January–March 1967	September 1967

1. Radiation Surveillance Network August 1967

National Center for Radiological Health
U.S. Public Health Service

Surveillance of atmospheric radioactivity in the United States is conducted by the Radiation Surveillance Network (RSN) which regularly gathers samples at 74 stations distributed throughout the country (figure 1). Most of the stations are operated by State health department personnel.

Daily samples of airborne particulates and precipitation are forwarded to the Radiation Surveillance Network Laboratory in Rockville, Md., for laboratory analysis. The alerting function of the network is provided by routine field estimates of the gross beta radioactivity by the station operators. These estimates are made after the decay of radon and partial decay of thoron daughter products and prior to submission of the samples for laboratory analysis. When high air levels are reported, appropriate officials are promptly notified. Compilation of field estimates and laboratory confirmations are reported elsewhere on a monthly basis (*1*). A detailed description of the sampling and analytical procedures was presented in the November 1966 issue of *Radiological Health Data and Reports*. The described procedures have been modified so that laboratory gross beta radioactivity analysis and gamma-ray spectroscopy are no longer performed on air samples having a field estimate below 10 pCi/m^3. Reporting field estimates only may cause an apparent increase in the published airborne radioactivity levels proportional to the amount of thoron daughter radioactivity present in the sample. In extreme cases, this increase may be as much as 2 orders of magnitude, but usually will be of the order of a factor of 2 or less. The maximum field estimates reported by the RSN stations attributable to thoron daughter radioactivity have ranged from 15 to 20 pCi/m^3 at 5 hours after collection.

Table 1 presents the monthly average gross beta radioactivity in surface air particulates, as measured by the field estimate, and deposition by precipitation during August 1967. Time profiles of gross beta radioactivity in air for eight RSN stations are shown in figure 2.

Figure 1. Radiation Surveillance Network sampling stations

Table 1. Gross beta radioactivity in surface air and precipitation, August 1967

Station locations		Number of samples		Air surveillance, gross beta radioactivity (pCi/m³)			Last profile in *RHD&R*	Precipitation	
		Air	Pptn	Maximum	Minimum	Average [a]		Total depth (mm)	Total deposition (nCi/m³)
Ala:	Montgomery	31	6	7.68	0.28	2.45	Nov 67	56	<11
Alaska:	Adak	31	----	.37	.37	.37	June 67	[b]	
	Anchorage	22	9	.00	.00	.00	Dec 67	67	<14
	Attu Island	[c]	----	----	----	----	July 67	[b]	
	Fairbanks	[c]	----	----	----	----	Jan 67	[b]	
	Juneau	18	15	.41	.00	.05	Apr 67	186	<37
	Kodiak	22	----	.90	.00	.31	May 67	[b]	
	Nome	[c]	----	----	----	----	Sept 67	[b]	
	Pt. Barrow	31	----	.65	.31	.61	Aug 67	[b]	
	St. Paul Island	[c]	----	----	----	----	Oct 67	[b]	
Ariz:	Phoenix	19	----	2.18	.87	1.53	Apr 67	[b]	
Ark:	Little Rock	29	6	2.90	.31	1.10	Dec 67	99	<20
Calif:	Berkeley	23	----	.47	.00	.09	May 67	[b]	
	Los Angeles	23	----	1.80	.24	.60	Sept 67	[b]	
C.Z:	Ancon	19	----	2.05	.47	1.07	May 67	[b]	
Colo:	Denver	30	5	6.00	.25	1.81	May 67	14	< 3
Conn:	Hartford	31	9	1.04	.00	.41	Apr 67	77	<15
Del:	Dover	22	----	1.50	.20	.42	Nov 67	[b]	
D.C:	Washington	28	10	2.40	.21	.76	Aug 67	242	<49
Fla:	Jacksonville	26	14	.38	.30	.34	Dec. 67	277	<55
	Miami	29	11	.29	.13	.23	Apr 67	164	<33
Ga:	Atlanta	27	7	1.89	.37	1.04	Oct 67	123	<25
Guam:	Agana	30	----	1.08	.00	.49	Nov 67	[b]	
Hawaii:	Honolulu	31	3	.64	.32	.36	July 67	85	<17
Idaho:	Boise	30	----	3.06	.78	1.90	July 67	[b]	
Ill:	Springfield	30	4	3.79	.74	2.10	Aug 67	56	<11
Ind:	Indianapolis	28	4	7.80	1.02	2.48	Oct 67	54	<11
Iowa:	Iowa City	27	5	4.60	.31	1.84	May 67	106	<21
Kans:	Topeka	25	6	8.16	.84	3.50	Dec 67	46	< 9
Ky:	Frankfort	30	7	8.37	1.11	2.65	Aug 67	44	< 9
La:	New Orleans	28	12	.55	.04	.22	Aug 67	261	<52
Maine:	Augusta	29	11	1.49	.21	.44	Sept 67	95	<19
	Presque Isle	11	1	1.78	.34	.78	May 67	6	< 1
Md:	Baltimore	23	6	2.81	.19	.66	Apr 67	145	<29
	Rockville	5	----	1.10	.07	.21	July 67	[b]	
Mass:	Lawrence	27	8	1.75	.00	.45	Nov 67	53	<11
	Winchester	19	10	1.31	.00	.31	June 67	61	<12
Mich:	Lansing	31	6	6.61	1.40	2.96	July 67	73	<15
Minn:	Minneapolis	23	5	.85	.17	.26	Nov 67	124	<25
Miss:	Jackson	29	3	2.18	.25	.98	Sept 67	57	<11
Mo:	Jefferson City	31	3	4.34	.59	1.92	Oct 67	50	<10
Mont:	Helena	31	3	2.80	.81	1.68	June 67	14	< 3
Nebr:	Lincoln	23	6	4.60	.77	1.99	Oct 67	49	<10
Nev:	Las Vegas	31	----	1.60	.47	.74	Jan 67	[b]	
N.H:	Concord	22	----	3.10	.46	1.12	Aug 67	[b]	
N.J:	Trenton	31	10	.58	.19	.29	Sept 67	46	< 9
N. Mex:	Santa Fe	30	14	1.83	.22	.79	June 67	80	<16
N.Y:	Albany	23	6	2.09	.20	.83	Oct 67	70	<14
	Buffalo	17	----	.67	.10	.28	May 67	[b]	
	New York	29	----	.38	.16	.23	June 67	[b]	
N.C:	Gastonia	1	6	5.78	5.78	5.78	May 67	145	<29
N. Dak:	Bismarck	30	5	5.09	.47	2.07	Aug 67	24	< 5
Ohio:	Cincinnati	13	----	7.12	.36	2.34	Nov 67	[b]	
	Columbus	29	1	7.01	.42	2.71	Sept 67	37	< 7
	Painesville	30	10	2.17	.32	1.13	Apr 67	41	< 9
Okla:	Oklahoma City	28	3	1.92	.00	1.01	July 67	59	<12
	Ponca City	25	6	1.39	.23	.72	Apr 67	42	< 8
Ore:	Portland	30	----	1.35	.22	.42	Oct 67	[b]	
Pa:	Harrisburg	28	3	4.24	.85	1.66	Oct 67	100	<20
P.R:	San Juan	23	5	1.22	.00	.24	Sept 67	79	<16
R.I:	Providence	27	5	.68	.00	.20	July 67	116	<23
S.C:	Columbia	16	9	11.61	.00	2.27	June 67	244	<49
S. Dak:	Pierre	31	2	9.40	1.92	4.55	Apr 67	10	< 2
Tenn:	Nashville	31	7	3.20	.30	1.16	July 67	42	< 9
Tex:	Austin	31	3	7.61	1.71	4.20	Nov 67	65	<13
	El Paso	30	4	3.44	.57	1.51	Aug 67	14	< 3
Utah:	Salt Lake City	31	4	1.35	.31	.92	Sept 67	5	< 1
Vt:	Barre	29	13	3.61	.24	1.65	Dec 67	92	<19
Va:	Richmond	27	10	1.63	.23	.77	Dec 67	157	<31
Wash:	Seattle	30	----	.43	.00	.14	Dec 67	[b]	
	Spokane	31	----	1.97	.65	1.17	Nov 67	[b]	
W. Va:	Charleston	31	9	3.92	.48	1.56	June 67	64	<13
Wis:	Madison	31	6	50.75	.18	2.61	Dec 67	57	<11
Wyo:	Cheyenne	31	3	5.72	2.19	3.80	Jan 67	23	< 5
Network summary		1,829	339	50.75	0.00	1.29		84	<17

[a] The monthly average is calculated by weighting the field estimates of individual air samples with length of sampling period. Values less than 0.005 pCi/m³ are reported and used in averaging as 0.00 pCi/m³.
[b] No precipitation sample collected.
[c] No report received.

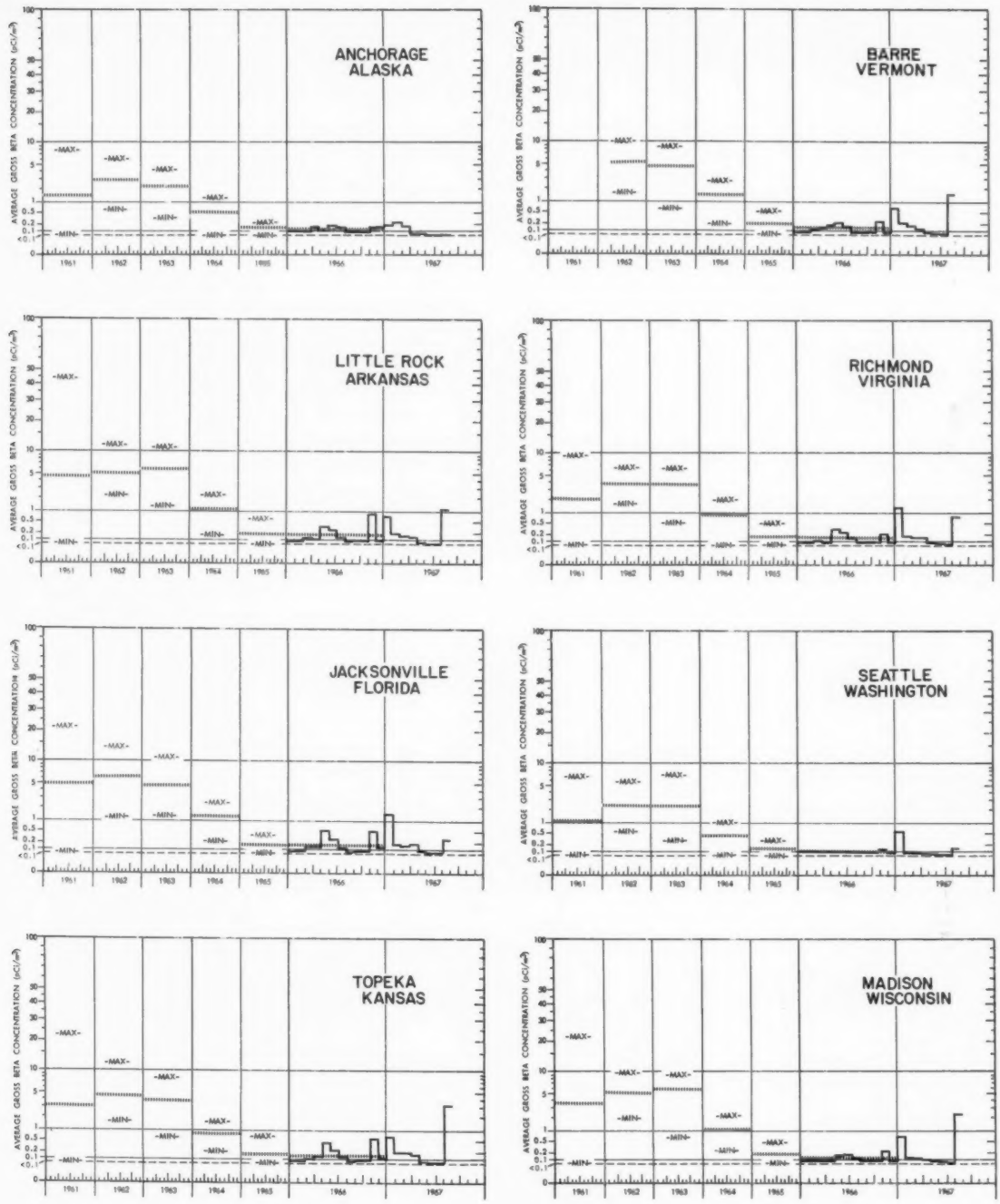

Figure 2. Monthly and yearly profiles of beta radioactivity in air—Radiation Surveillance Network, 1961–August 1967

Air and precipitation radioactivity levels remained near or below detectable levels. The only sample that contained a significant amount of radioactivity was the August 2 air sample from Madison, Wisc. This filter contained a single particle of radioactive material which emitted beta particles of about 1.75 MeV maximum energy, had a half life of approximately 15 days, and emitted no alpha or gamma radiation when analyzed in the laboratory on August 7-14. The material has been tentatively identified as phosphorus–32. The source of the contamination is not known.

2. Canadian Air and Precipitation Monitoring Program, August 1967 [1]

Radiation Protection Division, Department of National Health and Welfare

The Radiation Protection Division of the Canadian Department of National Health and Welfare monitors surface air and precipitation in connection with its Radioactive Fallout Study Program. Twenty-four collection stations are located at airports (figure 3), where the sampling equipmen its operated by personnel from the Meteorological Services Branch of the Department of Transport. Detailed discussions of the sampling procedures, methods of analysis, and interpretation of results of the radioactive fallout program are contained in reports of the Department of the National Health and Welfare (*2–6*).

A summary of the sampling procedures and methods of analysis was presented in the November 1966 issue of *Radiological Health Data and Reports.*

Surface air and precipitation data for August 1967 are presented in table 2.

[1] Prepared from information and data in the September 1967 monthly report "Data from Radiation Protection Program," Canadian Department of National Health and Welfare, Ottawa, Canada.

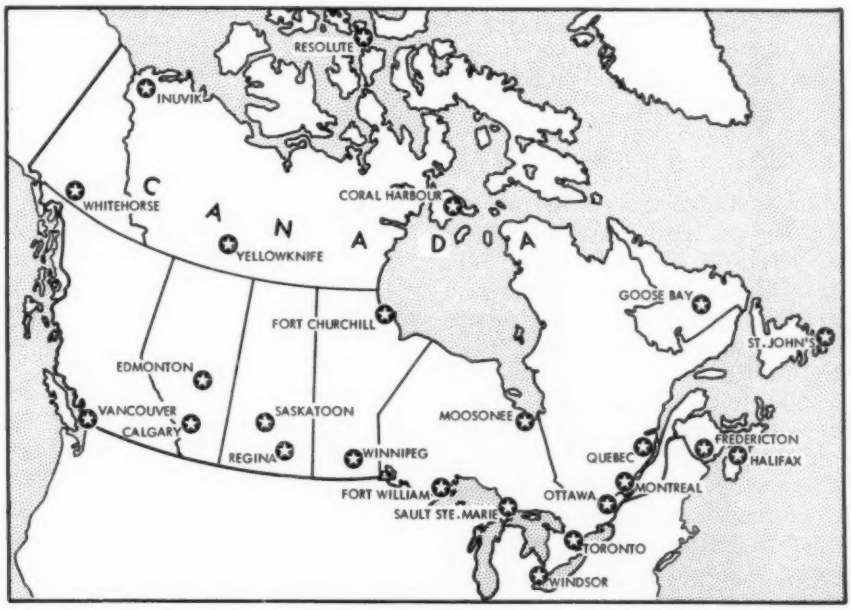

Figure 3. Canadian air and precipitation sampling stations

Table 2. Canadian gross beta radioactivity in surface air and precipitation, August 1967

Station	Number of samples	Air surveillance gross beta radioactivity (pCi/m³)			Precipitation measurements	
		Maximum	Minimum	Average	Average concentrations (pCi/liter)	Total deposition (nCi/m²)
Calgary	31	1.17	0.0	0.4	43	0.6
Coral Harbour	31	.0	.0	.0	15	.4
Edmonton	31	.0	.0	.0	18	.8
Ft. Churchill	31	.0	.0	.0	6	.3
Ft. William	31	.0	.0	.0	19	1.4
Fredericton	31	.0	.0	.0	10	.5
Goose Bay	30	.0	.0	.0	6	.6
Halifax	31	.0	.0	.0	5	.7
Inuvik	31	.0	.0	.0	9	.3
Montreal	30	.1	.0	.0	11	.8
Moosonee	31	.0	.0	.0	13	1.0
Ottawa	31	.0	.0	.0	12	.8
Quebec	31	.0	.0	.0	7	1.1
Regina	31	1.01	.0	.3	39	.7
Resolute	30	.0	.0	.0	NS	NS
St. John's, Nfld.	31	.0	.0	.0	11	.5
Saskatoon	31	1.15	.0	.4	12	.7
Saulte Ste Marie	31	.0	.0	.0	8	.7
Toronto	31	.0	.0	.0	20	.8
Vancouver	31	.0	.0	.0	48	.3
Whitehorse	31	.0	.0	.0	32	.3
Windsor	30	.0	.0	.0	11	1.0
Winnipeg	31	.0	.0	.0	16	.9
Yellowknife	31	.0	.0	.0	75	.3
Network summary	740	1.17	0.0	0.4	19	0.7

NS, no sample collected.

3. Mexican Air Monitoring Program August 1967

National Commission of Nuclear Energy

The Radiation Surveillance Network of Mexico was established by the Comisión Nacional de Energía Nuclear (CNEN), México, D.F. From 1952 to 1961, the network was directed by the Institute of Physics of the University of Mexico, under contract to the CNEN.

In 1961, the CNEN appointed its Division of Radiological Protection to establish a new Radiation Surveillance Network. In 1966, the Division of Radiological Protection was restructured and its name changed to Dirección General de Seguridad Radiológica (DRS). The network consists of 16 stations (figure 4), 11 of which are located at airports and operated by airline personnel. The remaining five stations are located at México, D.F.; Mérida; Veracruz; San Luis Potosí; and Ensenada. Staff members of the DRS operate the station at México, D.F., while the other four stations are manned by members of the Centro de Previsión del Golfo de México, the Chemistry Department of the University of Mérida, the Institute de Zonas Déserticas of the University of San Luis Potosí, and the Escuela Superior de Ciencias Marinas of the University of Baja California, respectively.

Sampling

The sampling procedure involves drawing air through a high-efficiency 6- by 9-inch glass fiber filter for 20 hours a day, 3 or 4 days a week at the rate of 1,000 cubic meters per day using high volume samplers.

After each 20 hour sampling period, the filter is removed and shipped via airmail to the Sección de Radioactividad Ambiental, CNEN, in México, D.F., for assay of gross beta radioactivity, allowing a minimum of 3 or 4 days after collection for the decay of radon and thoron. The data are not extrapolated to the time of collection. Statistically, it has been found that a minimum of five samples per month were needed to get a reliable average radioactivity at each station (*7*).

The maximum, minimum, and average gross beta radioactivity in surface air during August 1967 are presented in table 3.

Table 3. Mexican gross beta radioactivity of airborne particulates, August 1967

Station	Number of samples	Gross beta radoactivity (pCi/m³)		
		Maximum	Minimum	Average
Acapulco	6	0.2	<0.1	0.1
Chihuahua	9	.1	< .1	.1
Ciudad Juárez	6	.1	< .1	.1
Ensenada	17	.1	< .1	.1
Guadalajara	8	.1	< .1	< .1
Guaymas	NS			
La Paz	3	.1	< .1	
Matamoros	NS			
Mazatlán	12	.1	< .1	.1
Mérida	12	.2	< .1	.1
México, D.F.	20	.1	< .1	.1
Nuevo Laredo	NS			
San Luis Potosí	NS			
Tampico	11	.1	< .1	.1
Torreón	14	.1	< .1	< .1
Veracruz	21	.1	< .1	< .1

NS, no sample collected, station temporarily shut down.

Figure 4. Mexican air sampling locations

4. Pan American Air Sampling Program August 1967

Pan American Health Organization and *U.S. Public Health Service*

Gross beta radioactivity in air is monitored by countries in the Americas under the auspices of the collaborative program developed by the Pan American Health Organization (PAHO) and the U.S. Public Health Service (PHS) to assist PAHO-member countries in developing radiological health programs. The sampling equipment and analytical services are provided by the National Center for Radiological Health, PHS, and are identical with those employed for the Radiation Surveillance Network before July 31, 1967. The air sampling locations are shown in figure 5.

The August 1967 air monitoring results are given in table 4. Airborne gross beta radioactivity levels remained elevated at all reporting stations south of the equator although they were substantially lower than those reported for July 1967. Those samples more active than 1.0 pCi/m^3 at the time of collection are presented in table 5.

Figure 5. Pan American Air Sampling Program stations

Table 4. PAHO gross beta radioactivity in surface air August 1967

Station location	Number of samples	Gross beta radioactivity (pCi/m³)		
		Maximum	Minimum	Average [a]
Argentina: Buenos Aires	9	0.58	0.04	0.20
Bolivia: La Paz	19	1.73	.25	.90
Chile: Santiago	26	.88	.03	.36
Colombia: Bogota	21	.17	.00	.05
Ecuador: Guayaquil	30	.69	.04	.23
Jamaica: Kingston	12	.05	.01	.02
Peru: Lima	23	.83	.03	.37
Venezuela: Caracas	23	.17	.01	.05
West Indies: Trinidad	17	.19	.01	.06
Pan American summary	180	1.73	0.00	0.24

[a] The monthly average is calculated by weighting the individual samples with length of sampling period.

Table 5. Samples from PAHO member country which contained radioactivity greater than 1 pCi/m³

Location	Date August 1967	Gross beta radioactivity at collection (pCi/m³)
Bolivia: La Paz	5–6	1.73
	7–8	1.27
	9–11	1.29
	12–14	1.00
	15	1.60

REFERENCES

(1) PUBLIC HEALTH SERVICE, RADIATION SURVEILLANCE NETWORK. Monthly tabulation of findings. National Center for Radiological Health, Washington, D.C. 20201 (Distribution by official request).

(2) BIRD, P. M., A. H. BOOTH, and P. G. MAR. Annual report of 1959 on the Radioactive Fallout Study Program, CNHW–RP–3. Department of National Health and Welfare, Ottawa, Canada (May 1960).

(3) BIRD, P. M., A. H. BOOTH, and P. G. MAR. Annual report for 1960 on the Radioactive Fallout Study Program, CNHW–RP–4. Department of National Health and Welfare, Ottawa, Canada (December 1961).

(4) MAR, P. G. Annual report for 1961 on the Radioactive Fallout Study Program, CNHW–RP–5. Department of National Health and Welfare, Ottawa, Canada (December 1962).

(5) BEALE, J., and J. GORDON. The operation of the Radiation Protection Division Air Monitoring Program, RPD–11. Department of National Health and Welfare, Ottawa, Canada (July 1962).

(6) BOOTH, A. H. The calculation of permissible levels of fallout in air and water and their use in assessing the significance of 1961 levels in Canada, RPD–21. Department of National Health and Welfare, Ottawa, Canada (August 1962).

(7) VASQUEZ, M., and R. M. DE NULMAN. Estudios sobre la Radioactividad Ambiental en la República Mexicana, 1963–1965. Comisión Nacional de Energia Nuclear, Dirección General de Seguridad Radiológica (in press 1966).

SECTION IV. OTHER DATA

This section presents results from routine sampling of biological materials and other media not reported in the previous sections. Included here are such data as those obtained from human bone sampling, bovine thyroid sampling, Alaskan surveillance, and environmental monitoring in the vicinity of nuclear facilities.

Environmental Levels of Radioactivity at Atomic Energy Commission Installations

The U.S. Atomic Energy Commission receives from its contractors semiannual reports on the environmental levels of radioactivity in the vicinity of major Commission installations. The reports include data from routine monitoring programs where operations are of such a nature that plant environmental surveys are required.

Release of radioactive materials from AEC installations are governed by radiation protection standards set forth by AEC's Division of Operational Safety in directives published in the "AEC Manual." [1]

Summaries of the environmental radioactivity data follow for the Brookhaven National Laboratory and the Los Alamos Scientific Laboratory.

[1] Title 10, Code of Federal Regulations, Part 20, "Standards for Protection Against Radiation," contains essentially the standards published in Chapter 0524 of the AEC Manual.

1. Brookhaven National Laboratory January–June 1967 [2]

Associated Universities, Inc.
Upton, New York

The Brookhaven National Laboratory (BNL) operations may affect the environmental levels of radiation in three ways: (1) by discharge of coolant air from the graphite research reactor, (2) by radiation from an ecology forest gamma-ray source, and (3) by the discharge of low-level radioactive liquid wastes into a small stream that forms one of the headwaters of the Peconic River (figure 1).

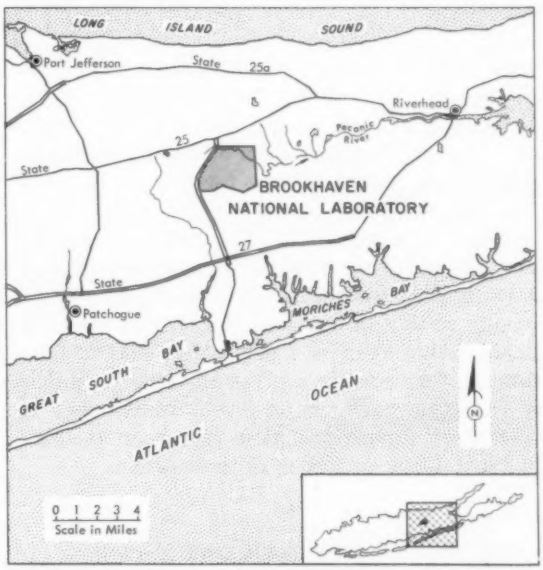

Figure 1. Brookhaven National Laboratory and surrounding area

[2] Summarized from "Effects of Brookhaven National Laboratory on Environmental Levels of Radioactivity during the First Half of 1967," Associated Universities Inc., Upton, N. Y.

Area monitoring

The radioactivity in the discharge coolant air is almost entirely due to argon–41, a beta-particle gamma-ray emitter. Monitoring for argon–41 is performed by continuously measuring the gamma-ray exposure rate in milliroentgens per week (mR/wk), rather than the concentration in air, at four stations located along the site perimeter (figure 2). These same stations monitor radioactivity resulting from a 10,000 curie cesium–137 gamma-ray source, situated in an ecology forest, about 800 meters equidistant from the north and east boundaries of the BNL.

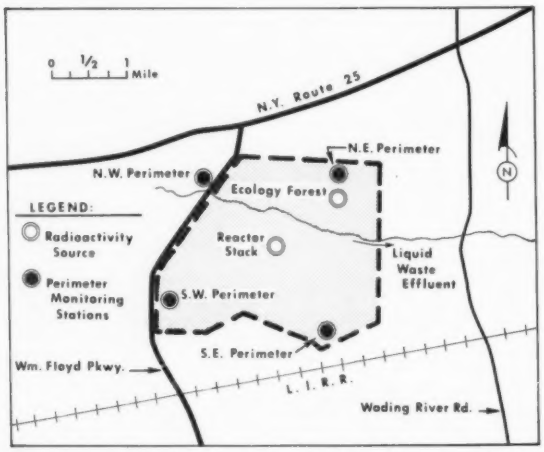

Figure 2. Brookhaven National Laboratory monitoring station locations

Radiation levels at the northeast perimeter are somewhat greater than at other monitoring stations due to the ecology forest source. However, the radiation levels at this location are within the established AEC radiation protection standard which is 0.5 rem/yr for individuals in the general population. The average weekly radiation levels at the Brookhaven National Laboratory site perimeter, due to laboratory operations, are given in table 1. Values of radiation background levels undisturbed by laboratory operations have also been included in table 1 for purposes of comparison.

Water monitoring

The liquid waste effluent from the laboratory sewage processing plant is monitored continuously at the point where the stream leaves the BNL site. The average concentration and total amount of gross beta radioactivity in the liquid waste effluent, at the site boundary, are shown in table 2 for January–June 1967.

Table 1. External gamma radioactivity at BNL site perimeter, January-June 1967

Period 1967	Average exposure rates (mR/wk)			
	Northwest perimeter	Southwest perimeter	Southeast perimeter	Northeast perimeter
January	0.04	0.28	0.52	1.76
February	.04	.10	.24	1.77
March	.09	.32	.25	1.52
April	.18	.14	.16	1.77
May	.29	.04	.45	2.25
June	.22	.09	.04	3.05
January-June	.15	.16	.28	2.02
Maximum weekly average	0.57	0.73	1.06	4.46
Undisturbed background	1.82	1.75	1.76	1.82

Table 2. Gross beta radioactivity in liquid waste effluent at BNL site boundary, January-June 1967

Period 1967	Average radioactivity concentration (pCi/liter)	Total radioactivity concentration discharged (mCi)
January	20	1.4
February	27	1.5
March	260	20.3
April	55	5.5
May	31	2.5
June	21	2.2
January-June	68	33.4

Analysis of composite samples of the effluent has shown that, on the average, no more than 20 percent of the radioactivity consists of strontium–90 and that no appreciable amounts of radioactive iodine or radium and other bone-seeking radionuclides are present. Under these conditions, the applicable AEC radiation protection standard for discharge of liquid waste to uncontrolled areas would be 3,000 pCi/liter.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
January–June 1966	December 1966
July–December and annual summary 1966	June 1967

2. Los Alamos Scientific Laboratory [3] Calendar Year 1966

University of California
Los Alamos, New Mexico

As part of the environmental monitoring program at Los Alamos, measurements of radioactivity in airborne particulates and precipitation are made periodically. The samples have been taken on the roof of building TA–50 (about 1¾ miles southeast of the Administrative Building) since March 1963.

Air monitoring

Airborne radioactive particulate matter is collected on 4-inch-diameter filters. The sampling rate was reduced from 46 m^3/hr in 1962 to 25.5 m^3/hr in 1963, due to the addition of an activated charcoal filter behind the first filter. Air samples are ordinarily collected for 24-hour intervals during the work week, 72-hour weekend samples are collected.

The filters are counted for beta radioactivity 7 days after collection in a thin-window methane-flow proportional counter with an overall efficiency for strontium-yttrium–90 of 50 percent.

In September 1966, a large chamber was added to the low background beta-particle counting system that permits the counting of these air samples in the same geometry as the precipitation samples. The efficiency for strontium-yttrium–90 remains the same as in the older counter.

Precipitation monitoring

Collection is made in a 0.4 square meter rain collector which delivers 1 liter of water for each 0.1 inch of precipitation. It has been found that this arrangement also collected radioactivity from dry deposition onto the collector. By washing down the sides of the collector with 1 liter of distilled water, a suitable sample is obtained. These "wash" samples, as well as any precipitation, are reduced in volume, dry-plated on 1-inch stainless steel planchets, and counted in an automatic beta-particle counting system.

Results

Average daily radioactivity concentrations for air collected are weighted for sample periods of more than 1 day. Average radioactivity concentrations for the precipitation collection are calculated from the total radioactivity collected during the month divided by the number of days in the month. Summary of air data (pCi/m^3) shows the maximum, 4.64; minimum, 0.00; and average, 0.15. Precipitation (nCi/m^2) shows the maximum, 4.2; minimum, 0.0; and average, 0.1. Total precipitation for the year was 43.6 nCi/m^2.

[3] Summarized from "Beta Radioactivity in Environmental Air and Precipitation at Los Alamos, New Mexico for 1966," (LA–3663).

Recent coverage in *Radiological Health Data:*

Period	Issue
1962–1963	October 1964
1964	November 1965

Reported Nuclear Detonations, November 1967

During November 1967, one U.S. underground nuclear test was announced by the Atomic Energy Commission. A nuclear test of low yield (less than 20 kilotons TNT equivalent) was conducted underground on November 8, 1967 by the Atomic Energy Commission at its Nevada Test Site.

Annual Subject Index

Radiological Health Data and Reports — Volume 8—1967

A

Aerial measurement of the Kiwi transient nuclear test, *July:359*
Air—*see* Atmospheric contaminants; Fallout
Alaska
  Radionuclides in Alaskan caribou and reindeer October–November 1966, *May:290*
Argonne National Laboratory
  Jan-June 1966, *Mar:177*
  July-Dec and annual summary 1966, *Sept:538*
Atmospheric contaminants
  Plutonium concentrations in ground level air and changes in plutonium–238 to plutonium–239 ratios, *Sept:561*
  Plutonium in airborne particulates
    July-Sept 1966, *Feb:108*
    Oct-Dec 1966, *May:288*
    Jan-Mar 1967, *Sept:534*
  Plutonium in airborne particulates and precipitation and strontium–90 in precipitation, April-June 1967, *PHS, Nov:662*
  Plutonium and strontium–90 in precipitation August 1966 through March 1967, *Oct:574*
  Radioactivity in airborne particulates and precipitation, *see* Canada; Mexico; 80th Meridian Network; Pan American Health Organization; Radiation Surveillance Network
  Surface Air Sampling Program—80th Meridian Network, January-December 1965, *Jan:37*
Atmospheric levels of radioactivity—*see* Atmospheric contaminants; Chinese nuclear testing; Environmental levels of radioactivity at Atomic Energy Commission installations; Fallout; Reported nuclear detonations
Atomic Energy Commission installations—*see* Argonne; Atomics International; Bettis; Brookhaven; Feed Materials Production Center; Feed Materials Production Facilities; Hanford; Knolls; Lawrence; Los Alamos; Mound; National; Oak Ridge; Paducah; Pinellas; Portsmouth; Rocky Flats, S1C; Savannah; Shippingport
Atomics International
  Jan-June 1966, *Mar:177*
  July-Dec 1966, *Aug:471*

B

Barium-lanthanum–140—*see* Atmospheric contaminants; Atomic Energy Commission installations; Fallout; Milk
Bettis Atomic Power Laboratory
  Jan-June 1966, *Apr:215*
Body burden
  Cesium–137 burdens of some Cincinnati residents, July 1964-March 1967, *Sept:559*
Bone
  Radionuclide levels in milk, total diet, and human bone compared to Federal Radiation Council estimates, 1965 and 1966 estimates, *Feb:65*
  Strontium–90 in human bone, *NCRH*
    Jan-Mar 1966, *Feb:110*
    Apr-June 1966, *Mar:173*
    July-Sept 1966, *July:403*
    Oct-Dec 1966, *Sept:535*
  Strontium–90 in human bones, 1964–1965, *Aug:415*
  Strontium–90 in human vertebrae, 1966, *HASL, Nov:664*
Bovine thyroids
  Iodine–131 in bovine thyroids
    Jan-June 1966, *Jan:51*
    July-Dec 1966, *Apr:227*
    Jan-Mar 1967, *Aug:465*
Brookhaven National Laboratory
  July-Dec and annual summary 1966, *June:347*
  Jan-June 1967, *Dec:729*

C

Calcium—*see also* Diet, Milk
  Distribution of strontium and calcium in major vegetable and fruit crops and criteria for use of fallout contaminated foods, *July:355*
California
  California Milk Network
    July-Sept 1966, *Mar:148*
    Oct-Dec 1966, *June:323*
    Jan-Mar 1967, *Sept:511*
    Apr-June 1967, *Dec:711*
  Diet model for measuring radioactivity exposure through food—pilot study, *Oct:565*
  Estimated daily intake of radionuclides in California diets
    Jan-Apr 1966, *Jan:19*
    May-Aug 1966, *May:271*
    Sept Dec 1966, Jan-Feb 1967, *Oct:596*
  Radioactivity in California waters
    Jan-June 1966, *June:335*
Canada
  Canadian Air and Precipitation Monitoring Program
    Sept 1966, *Jan:32*
    Oct 1966, *Feb:105*
    Nov 1966, *Mar:166*
    Dec 1966, *Apr:221*
    Jan 1967, *May:285*
    Feb 1967, *June:343*
    Mar 1967, *July:339*
    Apr 1967, *Aug:461*
    May 1967, *Sept:528*
    June 1967, *Oct:609*
    July 1967. *Nov:659*
    Aug 1967, *Dec:725*
  Canadian Milk Network
    Sept 1966, *Jan:9*
    Oct 1966, *Feb:83*
    Nov 1966, *Mar:145*
    Dec 1966, *Apr:200*
    Jan 1967, *May:258*
    Feb 1967, *June:321*
    Mar 1967, *July:379*
    Apr 1967, *Aug:429*
    May 1967, *Sept:507*
    June 1967, *Oct:581*
    July 1967, *Nov:632*
    Aug 1967, *Dec:708*
Caribou
  Radionuclides in Alaskan caribou and reindeer, October-November 1966, *May:290*
Cesium–137—*see also* Alaska; Diet; Food; Milk
  Cesium–137 burdens of some Cincinnati residents, July 1964-March 1967, *Sept:559*
  Cesium–137 in Tri-City diets, 1965, *HASL, Mar:154*
  Strontium–90, cesium–137, and polonium–210 in human tissues, *May:298*

Uptake of cesium–137 from contaminated soil by selected grass crops, *Aug:421*
Chinese nuclear testing—*see also* Fallout; Reported nuclear detonations
Fallout from the third Chinese nuclear test May 9, 1966, *June:301*
Coast Guard
Radionuclide analysis of Coast Guard water supplies, January-December 1966, *Nov:652*
Colorado
Colorado Milk Network
Jan-Mar 1967, *Jul:381*
Apr-June 1967, *Oct:583*
Color television receivers
Measurements of X-ray exposure from a home color television receiver, *Dec:687*
X-ray patterns and intensities from high voltage shunt regulator tubes for color television receivers, *Dec:675*
Connecticut
Connecticut Milk Network
July-Sept 1966, *Feb:85*
Oct-Dec 1966, *May:261*
Jan-Mar 1967, *Aug:432*
Apr-June 1967, *Nov:635*
Estimated daily intake of radionuclides in Connecticut standard diet
July-Dec 1966, *May:274*
Jan-June 1967, *Nov:646*
Gross beta radioactivity in *Fucus hybrids* (rockweed) from the Niantic Estuary, Connecticut, 1961–1964, *Aug:481*
Countermeasures
Status of full scale strontium–90 removal system for fluid milk, *NCRH, June:353*

D

Detonations, Nuclear—see Chinese nuclear detonations; Nuclear tests; Reported nuclear detonations
Diet
A proposed radioactivity concentration guide for shellfish, *Sept:491*
Cesium–137 in Tri-City diets, 1965, *HASL, Mar:154*
Diet model for measuring radioactivity exposure through food—pilot study, *Oct:565*
Distribution of strontium and calcium in major vegetable and fruit crops and criteria for use of fallout contaminated foods, *July:355*
Estimated daily intake of radionuclides in diets—*see* California; Connecticut
Plutonium–239 in total diet and milk, *Apr:191*
Radiological monitoring of the native Texas commercial oyster, *May:296*
Radionuclide levels in milk, total diet, and human bone compared to Federal Radiation Council estimates, 1965 and 1966 estimates, *Feb:65*
Radionuclides in Institutional diet samples, *HASL*
Apr-June 1966, *Jan:15*
July-Sept 1966, *Apr:209*
Oct-Dec 1966, *July:388*
Jan-Mar 1967 and annual summary 1966, *Oct:591*
Strontium–90 dietary intake estimates based on fractional intakes due to milk, *Feb:73*
Strontium–90 in Tri-City diets, *HASL*
May-June 1966, *June:329*
Aug-Dec 1966, *Sept:517*

E

Environmental levels of radioactivity at Atomic Energy Commission installations—*see* Atomic Energy Commission installations
Environmental surveillance, *see also* Coast Guard
Environmental radioactivity in woods soil from Dover, New Jersey, during 1964–1966, *Sept:553*
Gross beta radioactivity in *Fucus hybrids* (rockweed) from the Niantic Estuary, Connecticut, 1961–1964, *Aug:481*
Radioactivity in the Mexican environment, *Sept:495*
The Galveston environmental surveillance program 1966, *Aug:484*
Exposures
A summary of exposures to the offsite population as a result of nuclear reactor tests conducted at the nuclear rocket development station during 1965, *Jan:1*
Measurements of X-ray exposure from a home color television receiver, *Dec:687*
Summary of population exposure to X-rays in the United States, 1964, *July:367*

F

Fallout
Distribution of strontium and calcium in major vegetable and fruit crops and criteria for use of fallout contaminated foods, *July:355*
Fallout from the third Chinese nuclear test, May 9, 1966, *June:301*
Fallout in the United States and other areas, *HASL*
Jan-June 1966, *Mar:169*
July-Dec 1966, *Sept:531*
Federal Radiation Council—*see also* Bone; Diet; Milk
Radionuclide levels in milk, total diet, and human bone compared to Federal Radiation Council estimates, 1965 and 1966 estimates, *Feb:65*
Feed Materials Production Center
Jan-June 1966, *Apr:237*
July-Dec 1966, *Aug:474*
Feed Materials Production Facilities
Jan-June 1966, *Mar:184*
Florida
Florida Milk Network
Jan-June 1967 and summary 1966, *Oct:585*
Food—*see also* Diet; Milk; Wheat
Diet model for measuring radioactivity exposure through food—pilot study, *Oct:565*
Distribution of strontium and calcium in major vegetable and fruit crops and criteria for use of fallout contaminated foods, *July:355*

G

Galveston environmental surveillance program, 1966, *Aug:484*
Gamma radioactivity—*see* Atmospheric contaminants, Atmospheric levels of radioactivity
Guide
A proposed radioactivity concentration guide for shellfish, *Sept:491*
State Health Department sampling criteria for surveillance of radioactivity in milk, *Nov:621*

H

Hanford Atomic Products Operation
Calendar year 1965, *Feb:113*

I

Indiana
Indiana Milk Network
July-Sept 1966, *Feb:86*
Oct-Dec 1966, *May:262*
Jan-Mar 1967, *Aug:433*
Apr-June 1967, *Nov:636*

Industrial exposure
Radioactive material handling problems in oil and gas well logging, *Aug:487*
Radiation hazards from X-ray diffraction equipment, *May:245*
Radiation hazards in uranium mines, *Mar:135*
Institutional Total Diet Sampling Network—*see* Diet
Iodine–131—*see also* Fallout; Milk
Iodine–131 in bovine thyroids, *PHS*
Jan-June 1966, *Jan:51*
July-Dec 1966, *Apr:227*
Iowa
Iowa Milk Network
Jan 1965-Mar 1967, *Aug:435*
Apr-June 1967, *Nov:637*

J, K, L

Kiwi
Aerial measurement of the Kiwi transient nuclear test, *July:359*
Knolls Atomic Power Laboratory
Jan-June 1966, *Apr:239*
July-Dec 1966, *Oct:615*
Lawrence Radiation Laboratory
Jan-June 1966, *June:349*
July-Dec 1966, *Nov:668*

M

Mexico
Mexican Air Monitoring Program
Sept 1966, *Jan:33*
Oct 1966, *Feb:106*
Nov 1966, *Mar:167*
Dec 1966, *Apr:222*
Jan 1967, *May:287*
Feb 1967, *June:344*
Mar 1967, *July:400*
Apr 1967, *Aug:462*
May 1967, *Sept:529*
June 1967, *Oct:610*
July 1967, *Nov:660*
Aug 1967, *Dec:726*
Radioactivity in the Mexican environment, *Sept:495*
Michigan
Michigan Milk Network
July-Sept 1966, *Feb:88*
Oct-Dec 1966, *May:263*
Jan-Mar 1967, *Aug:436*
Milk
National and International milk surveillance—*see* Canada; Pan American Health Organization; Pasteurized Milk Network
Plutonium–239 in total diet and milk, *Apr:191*
Radionuclide levels in milk, total diet, and human bone compared to Federal Radiation Council estimates, 1965 and 1966 estimates, *Feb:65*
Radiostrontium in milk, *HASL, see also* State milk surveillance activities
Jan-June 1966, *Mar:147*
July-Dec 1966, *Sept:509*
State Health Department sampling criteria for surveillance of radioactivity in milk, *Nov:621*
State milk surveillance networks—*see* California; Colorado; Connecticut; Florida; Indiana; Iowa; Michigan; Minnesota; New York; Oklahoma; Oregon; Pennsylvania; Tennessee; Texas; Washington
Status of full scale strontium–90 removal system for fluid milk, *June:353*
Strontium–90 dietary intake estimates based on fractional intakes due to milk, *Feb:73*
Minnesota
Minnesota Milk Network
July-Sept 1966, *Feb:90*
Oct-Dec 1966, *May:265*
Jan-Mar 1967, *Aug:438*
Radioactivity in Minnesota municipal water supplies, January-June 1966, *Jan:26*
July-December 1966, *Oct:603*
Mound Laboratory
Jan-June 1966, *May:292*
July-Dec and annual summary 1966, *Nov:*

N

National Air Sampling Network
July-Sept 1966, *Jan:35*
Oct-Dec 1966 and annual summary 1966, *Apr:224*
(*The NASN has discontinued the measurement of radioactivity on its air samples*)
National and International milk surveillance—*see* Milk
National Reactor Testing Station
Jan-June 1966, *Mar:187*
July-Dec and calendar year 1966, *Sept:542*
New York
New York Milk Network
July-Sept 1966, *Feb:92*
Oct-Dec 1966, *May:267*
Jan-Mar 1967, *Aug:441*
Apr-June 1967, *Nov:642*
Radioactivity in New York surface waters
Jan-Dec 1966, *Sept:522*
Nuclear detonations—*see* Reported nuclear detonations; nuclear tests
Nuclear tests—*see also* Chinese nuclear tests
Aerial measurement of the Kiwi transient nuclear test, *July:359*
Summary of exposures to the offsite population as a result of nuclear reactor tests conducted at the nuclear rocket development station during 1965, *Jan:1*
Nuclear power ships—*see* Waste disposal

O

Oak Ridge Area
Jan-June 1966, *Jan:56*
July-Dec 1966, *Aug:476*
Oklahoma
Oklahoma Milk Network
July-Sept 1966, *Jan:11*
Oct-Dec 1966, *Apr:203*
Jan-Mar 1967, *July:383*
Oregon
Oregon Milk Network
July-Sept 1966, *Mar:150*
Oct-Dec 1966, *June:325*
Jan-Mar 1967, *Sept:513*
Oyster—*see* Shellfish

P

Paducah Plant
Jan-June 1966, *Jan:60*
July-Dec and calendar year 1966, *July:406*
Pan American Health Organization
Pan American Air Sampling Program
Sept 1966, *Jan:34*
Oct 1966, *Feb:106*
Nov 1966, *Mar:168*
Dec 1966, *Apr:223*
Jan 1967, *May:287*
Feb 1967, *June:345*
Mar 1967, *July:401*
Apr 1967, *Aug:463*
May 1967, *Sept:530*
June 1967, *Oct:611*
July 1967, *Nov:661*
Aug 1967, *Dec:727*
Pan American Milk Sampling Program
Sept 1966, *Jan:10*
Oct 1966, *Feb:84*
Nov 1966, *Mar: 146*
Dec 1966, *Apr:201*
Jan 1967, *May:259*
Feb 1967, *June:322*
Mar 1967, *July:380*
Apr 1967, *Aug:430*
May 1967, *Sept:508*
June 1967, *Oct:582*
July 1967, *Nov:633*
Aug 1967, *Dec:708*

Particulates—*see* Atmospheric contaminants; Fallout; Nuclear tests, Radiation Surveillance Network
Pasteurized Milk Network
Sept 1966, *Jan:6*
Oct 1966, *Feb:80*
Nov 1966, *Mar:140*
Dec 1966, *Apr:196*
Jan 1967, *May:252*
Feb 1967, *June:318*
Mar 1967, *July:376*
Apr 1967, *Aug:426*
May 1967, *Sept:504*
June 1967, *Oct:578*
July 1967, *Nov:629*
Aug 1967, *Dec:704*
Pennsylvania
Pennsylvania Milk Network
July-Sept 1966, *Feb:95*
Oct-Dec 1966, *May:269*
Jan-Mar 1967, *Aug:443*
Apr-June 1967, *Nov:*
Pinellas Peninsula Plant
Jan-June 1966, *Feb:124*
July-Dec 1966, *July:409*
Plutonium—*see also* Atmospheric contaminants
Plutonium and strontium-90 in precipitation, August 1966 through March 1967, *Oct:574*
Plutonium concentration in ground level air and changes in plutonium-238 to plutonium-239 ratios, *Sept:561*
Plutonium-239 in total diet and milk, *Apr:191*
Polonium-210
Strontium-90, cesium-137 and polonium-210 in human tissues, *May:298*
Portsmouth Area Gaseous Diffusion Plant
Jan-June 1966, *Jan:62*
July-Dec 1966, *Sept:545*
Precipitation—*see also* Atmospheric contaminants; Fallout; Radiation Surveillance Network, Strontium-90
Plutonium and strontium-90 in precipitation, August 1966 through March 1967, *Oct:574*
Proposed radioactivity concentration guide for shellfish, *Sept:491*

R

Radiation hazards in uranium mines, *Mar:135*
Radiation hazards from X-ray diffraction equipment, *May:245*
Radiation Surveillance Network
Sept 1966, *Jan:29*
Oct 1966, *Feb:135*
Nov 1966, *Mar:190*
Dec 1966, *Apr:244*
Jan 1967, *May:299*
Feb 1967, *June:340*
Mar 1967, *July:396*
Apr 1967, *Aug:458*
May 1967, *Sept:525*
June 1967, *Oct:606*
July 1967, *Nov:656*
Aug 1967, *Dec:722*
Radioactive material handling problems in oil and gas well logging, *Aug:487*
Radioactivity in the Mexican environment, *Aug:495*
Radiological monitoring of the native Texas commercial oyster, *May:296*
Radionuclides in Institutional diet samples, *see* Diet
Radionuclide levels in milk, total diet, and human bone compared to Federal Radiation Council estimates, 1965, and 1966 estimates, *Feb:65*
Reindeer—*see* Caribou
Reported nuclear detonations
Dec 1966, *Jan:64*
Jan 1967, *Feb:135*
Feb 1967, *Mar:190*
Mar 1967, *Apr:244*
Apr 1967, *May:299*
May 1967, *June:354*
June 1967, *July:413*
July 1967, *Aug:489*
Aug 1967, *Sept:563*
Sept 1967, *Oct:619*
Oct 1967, *Nov:673*
Nov 1967, *Dec:732*
Rocky Flats Plant
July-Dec and annual summary 1966, *May:294*

S

S1C Prototype Reactor Facility
Jan-June 1966, *Apr:241*
July-Dec 1966, *Oct:617*
Savannah River Plant
Jan-June 1966, *Feb:126*
July-Dec 1966, *Sept:546*
Shellfish
A proposed radioactivity concentration guide for shellfish, *Sept:491*
Radiological monitoring of the native Texas commercial oyster, *May:296*
Shippingport Atomic Power Station
Jan-June 1966, *Feb:131*
July-Dec and calendar year 1966, *July:410*
Soils
Environmental radioactivity in woods soil from Dover, New Jersey during 1964–1966, *Sept:553*
Uptake of cesium-137 from contaminated soil by selected grass crops, *Aug:421*
State Health Department sampling criteria for surveillance of radioactivity in milk, *Nov:621*
State milk surveillance activities—*see* California, Colorado; Connecticut; Florida; Indiana; Iowa; Michigan; Minnesota; New York; Oklahoma; Oregon; Pennsylvania; Tennessee; Texas; Washington
Status of full scale strontium-90 removal system from fluid milk, *June:353*
Strontium-90—*see also* Alaska; Atmospheric contaminants; Bone; Diet; Environmental levels at AEC installations; Food; Milk; Water
Distribution of strontium and calcium in major vegetable and fruit crops and criteria for use of fallout contaminated foods, *July:355*
Plutonium and strontium-90 in precipitation, August 1966 through March 1967, *Oct:574*
Strontium-90, cesium-137, and polonium-210 in human tissues, *May:298*
Strontium-90 dietary intake estimates based on fractional intakes due to milk, *Feb:73*
Strontium-90 in human bones, 1964–1965, *Aug:415*
Summary of exposures to the offsite population as a result of nuclear reactor tests conducted at the nuclear rocket development stations during 1965, *Jan:1*
Summary of population exposure to X-rays in the United States, 1964, *July:367*

T

Tennessee
Tennessee Milk Network
July 1965-June 1966, *Apr:205*
Jan-Mar 1967, *July:384*
Apr-June 1967, *Oct:588*
Texas
Galveston environmental surveillance program, 1966, *Aug:484*
Texas Milk Network
July-Sept 1966, *Jan:13*
Oct-Dec 1966, *Apr:207*
Jan-Mar 1967, *July:385*
Apr-June 1967, *Oct:589*
Radiological monitoring of the native Texas commercial oyster, *May:296*
Thyroid—*see* Bovine thyroids
Tri-City diet study—*see* Diet

U, V

Uranium
Radiation hazards in uranium mines, *Mar:135*
Vertebrae—*see* Bone

W

Washington
Washington Milk Network
July-Sept 1966, *Mar:151*
Oct-Dec 1966, *June:326*

Jan-Mar 1967, *Sept:514*
Apr-June 1967, *Dec:714*
Radioactivity in Washington surface water
July 1965-June 1966, *Aug:452*
Waste disposal
Disposal of radioactive wastes from U.S. Naval nuclear powered ships and their support facilities, *Dec:690*
Water—*see also* Atomic Energy Commission installations; California; Coast Guard; Minnesota; New York; Tap water; Washington
Galveston Environmental Surveillance Program, 1966, *Aug:484*
Gross radioactivity in surface waters of the United States, *FWPCA*
July 1966, *Jan:23*
Aug 1966, *Feb:98*
Sept 1966, *Mar:159*
Oct 1966, *Apr:214*
Nov 1966, *May:278*
Dec 1966, *June:332*
Jan 1967, *July:393*
Feb 1967, *Aug:447*
Mar 1967, *Sept:520*
Apr 1967, *Oct:601*
May 1967, *Nov:649*
June 1967, *Dec:718*
Radioactivity in the Mexican environment, *Aug:495*
Radiostrontium in tap water, *HASL*
Mar-Nov 1966, *June:334*
July-Dec 1966, *Nov:651*
Strontium-90 in surface waters of the United States
Oct 1965-June 1966, *Aug:447*

X, Y, Z

X ray
Measurement of X-ray exposure from a home color television receiver, *Dec:687*
Radiation hazards from X-ray diffraction equipment *May:245*
Summary of population exposure to X rays in the United States, 1964, *July:367*
X-ray patterns and intensities from high voltage shunt regulator tubes for color television receivers, *Dec:675*

Author Index

Radiological Health Data and Reports — Volume 8—1967

Andrews, V. E. ---- July:359

Baratta, E. J. ---- May:298
Barete, M. Vasquez ---- Sept:495
Bonner, W. P. ---- Aug:421
Briscoe, O. G. ---- Dec:687

Cohen, N. L. ---- Oct:565
Coleman, R. D. ---- July:359
Cromroy, H. L. ---- Aug:421

Ferri, Mrs. E. S. ---- May:298
Flora, D. H. ---- Aug:487
Fontaine, J. H. ---- Aug:487

Goldsmith, W. A. ---- Aug.421
Grundy, R. D. ---- Feb:73, June:301
Guckeen, T. R. ---- July:355

Hallisey, R. M. ---- Aug:415
Hatfield, T. W. ---- Aug:481
Helf, S. ---- Sept:553
Holaday, D. A. ---- Mar:135
Howley, J. R. ---- May:245
Hutson, E. ---- Oct:565

Kauffman, P. E. ---- Apr:191
Kirk, W. P. ---- Oct:574
Kolde, H. E. ---- Sept:559
Kunkel, H. ---- Oct:565

Lamb, F. C. ---- July:355
Lee, T. R. ---- Dec:687
Levine, H. ---- Oct:574

Maagdenberg, H. J. ---- July:355
Magno, P. J. ---- Apr:191, Sept:561
Mageno, J. J. ---- Dec:690
Marshall, N. ---- Aug:481
Mercer, W. A. ---- July:355
Miles, M. E. ---- Dec:690
Modine, N. F. ---- Dec:675
Murphy, E. G. ---- Dec:675

Neill, R. H. ---- Nov:621
Nulman, R. M. ---- Sept:495

Oakley, D. T. ---- Jan:1

Phillips, C. R. ---- Aug:421
Primbsch, S. ---- July:355

Ralls, J. W. ---- July:355
Rechen, H. J. L. ---- Oct:574, Dec:687
Rinehart, J. ---- July:355
Robbins, C. ---- May:245
Rolofson, J. W. ---- Dec:675

Schleien, B. ---- Sept:561
Schneider, R. H. ---- Dec:687
Skauen, D. M. ---- Aug:481
Snavely, D. R. ---- June:301, Nov:621
Stanko, J. J. ---- May:296
Steinkamp, R. C. ---- Oct:565
Stewart, B. ---- Aug:484
Stewart, H. F. ---- Dec:675

Wall, M. A. ---- Aug:415
Weaver, C. L. ---- Sept:491
Wukasch, M. C. ---- May:296, Aug:484

Acknowledgements

Consultant-Contributors for 1967

The publishers and staff of *Radiological Health Data and Reports* acknowledge with appreciation the valued services this past year of the following consultant editors from the staffs of our editorial advisory agencies:

Walter G. Belter
Dr. Martin B. Biles
Miss C. Patricia Dalton
Edward Hardy
John H. Harley
Philip Krey
Dr. Albert R. Landgrebe
Roy D. Maxwell
Thomas F. McCraw
James E. Miller
William J. Perkins
Joseph Rivera
Dr. Rafael Rodriguez Pasques
Arthur A. Schoen
Herbert Volchok
Carl G. Welty, Jr.

SYNOPSES

Synopses of reports, incorporating a list of key words, are furnished below in reference card format for the convenience of readers who may wish to clip them for their files.

X-RAY PATTERNS AND INTENSITIES FROM HIGH VOLTAGE SHUNT REGULATOR TUBES FOR COLOR TELEVISION RECEIVERS. *H. F. Stewart, N. F. Modine, E. G. Murphy* and *J. W. Rolofson. Radiological Health Data and Reports, Vol. 8, December 1967, pp. 675–686.*

Recently, X-ray emission from some color television receivers greater than the NCRP recommended maximum came to the attention of the Public Health Service. The radiation came from a high voltage shunt regulator tube. This discovery prompted a general investigation by the Public Health Service of radiation emission from regulator tubes used in color television receivers. This report describes the construction of high voltage shunt regulator tubes, laboratory test methods, and the measured X-ray distributions in direction, quality and intensity from 327 shunt regulator tubes.

KEYWORDS: Shunt regulator tubes, television receivers, X ray.

MEASUREMENTS OF X-RAY EXPOSURE FROM A HOME COLOR TELEVISION RECEIVER. *H. J. Reehen, T. R. Lee, R. H. Schneider,* and *O. G. Briscoe. Radiological Health Data and Reports. Vol. 8, December 1967, pp. 687–697.*

A detailed examination of X-ray leakage has been made for two prototypes of the KC chassis manufactured by General Electric Company for home color television receivers. Typical operating conditions relevant to X-ray production from the high voltage shunt regulator tube and the cathode ray tube are presented. A selected 6EF4 tube, under operating conditions chosen to produce maximum X-ray emission, produces an exposure rate of 83 R/hour immediately at the floor level under a console receiver, and a calculated maximum exposure rate of 800 R/hour below the receiver.

The results of using two different instruments to measure X-ray exposure rates are given, an ion chamber and X-ray film, and the results compare within reasonable limits. Preliminary findings of X-ray emission from the high voltage rectifier tubes are discussed. Little is known of the mechanisms that cause rectifiers to emit X rays, or how such emissions may be controlled other than by shielding.

KEYWORDS: Exposure rates, rectifier tubes, shunt regulator tubes, television receivers, X ray.

ORDER BLANK FOR RHD&R

To: Superintendent of Documents
Government Printing Office
Washington, D.C. 20402

Please enter my subscription for Radiological Health Data and Reports. I am enclosing Money Order ☐ Check ☐ for this subscription. ($5.00 a year; $1.50 additional for foreign mailing.)

Please address RHD&R as follows._____

_____

_____

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON, D.C., 1967

For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402
Subscription price $5.00 a year, $1.50 additional for foreign mailing.
Price for a single copy of this issue is 50 cents.

December 1967

GUIDE FOR AUTHORS

The editorial staff invites reports and technical notes containing information related to radiological health. Proposed reports and notes should contain data and interpretations. All accepted manuscripts are subject to copy editing with approval of the author. The author is responsible for all statements made in his work.

Manuscripts are received with the understanding that other identical manuscripts are not under simultaneous consideration nor have appeared in any other publication.

The mission of *Radiological Health Data and Reports* is stated on the title page. It is suggested that authors read it for orientation of subject matter.

Submission of manuscripts

Send original and one legible copy of the paper, typed double-spaced on 8½ by 11-inch white bond with 1-inch margins.

Submitted manuscripts should be sent to Managing Editor, Radiological Health Data and Reports, National Center for Radiological Health, PHS, Rockville, Md. 20852.

Preparation of manuscripts

The Government Printing Office style manual is used as a general guide in the preparation of all copy for *Radiological Health and Reports*. In addition, *Radiological Health Data and Reports* has developed a "Guide" regarding manuscript preparation which is available upon request. However, for most instances, past issues of *Radiological Health Data and Reports* would serve as a suitable guide in preparing manuscripts.

Titles, authors: Titles should be concise and informative enough to facilitate indexing. Names of authors should appear on the third line below the manuscript title. Affiliation of each author should be given by a brief footnote including titles, professional connections at the time of writing, present affiliation if different, and present address.

Abstracts: Manuscripts should include a 100- to 150-word abstract which is a factual (not descriptive) summary of the work. It should clearly and concisely state the purpose of the investigation, methods, results, and conclusions. Findings that can be stated clearly and simply should be given rather than to state that results were obtained.

A list of suggested keywords (descriptors) which are appropriate indexing terms should be given following the abstract.

Introductory paragraph: The purpose of the investigation should be stated as early as possible in the introductory paragraph.

Methods: For analytical, statistical, and theoretical methods that have appeared in published literature, a general description with references to sources is sufficient. New methods should be described clearly and concisely with emphasis on new features. Both old and new methods, materials, and equipment, should be described clearly enough so that limitations of measurements and calculations will be clear to the readers. Errors associated with analytical measurements and related calculations should be given either as general estimates in the text or for specific data in appropriate tables or graphs, whenever possible.

Illustrations: Glossy photographic prints or original illustrations suitable for reproduction which help enhance the understanding of the text should be included with the manuscript. Graphic materials should be of sufficient size so that lettering will be legible after reduction to printed page size (8½ by 6½ inches).

All illustrations should be numbered and each legend should be typed double-spaced on a separate sheet of paper. Legends should be brief and understandable without reference to text. The following information should be typed on a gummed label of adhesive strip and affixed to the back of each illustration: figure number, legend, and title of manuscript or name of senior author.

Tables: Tables should be self-explanatory and should supplement, not duplicate, the text. Each table should be typed on a separate sheet, double-spaced. All tables must be numbered consecutively, beginning with 1, and each must have a title.

Equations: All equations must be typewritten, preferably containing symbols which are defined immediately below the equation. The definition of symbols should include the units of each term. Special symbols, such as Greek letters, may be printed carefully in the proper size, and exponents and subscripts should be clearly positioned. Mathematical notations should be simple, avoiding when feasible, such complexities as fractions with fractions, subscripts with subscripts, etc.

Symbols and units: The use of internationally accepted units of measurements are preferred. A brief list of symbols and units commonly used in *Radiological Health Data and Reports* is given on the inside front cover of every issue and examples of most other matters of preferred usage may be found by examining recent issues. Isotope mass numbers are placed at the upper left of elements in long series or formulas, *e.g.*, ^{137}Cs; however, elements are spelled out in text and tables, with isotopes of the elements having a hyphen between element name and mass number; *e.g.*, strontium–90.

References: References should be typed on a separate sheet of paper.

Personal communications and unpublished data should not be included in the list of references. The following minimum data for each reference should be typed double-spaced: names of all authors in caps, complete title of article cited, name of journal abbreviated according to *Index Medicus*, volume number, first and last page numbers, month or week of issue, and year of publication. They should be arranged according to the order in which they are cited in the text, and not alphabetically. All references must be numbered consecutively.

Reprints

Contributors are ordinarily provided with 50 courtesy copies of the articles in the form of reprints. In cases of multiple authorship, additional copies will be provided for coauthors upon request.

U.S. DEPARTMENT OF
HEALTH, EDUCATION, AND WELFARE
PUBLIC HEALTH SERVICE
WASHINGTON D.C. 20201

OFFICIAL BUSINESS

POSTAGE AND FEES PAID
U.S. DEPARTMENT OF H.E.W.

If you do not desire to continue receiving this publication, please CHECK HERE ☐; tear off this label and return it to the above address. Your name will then be promptly removed from the appropriate mailing list.